Systems Analysis Department annual progress report 1996

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SYSTEMS ANALYSIS DEPARTMENT

ANNUAL PROGRESS REPORT 1996

Edited by Hans Larsen, Charlotte Olsson and Kurt E. Petersen
Risø National Laboratory · Roskilde · Denmark

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ABSTRACT

The report describes the work of the Systems Analysis Department at Risø National Laboratory during 1996. The department is undertaking research within Simulation and Optimisation of Energy Systems, Energy and Environment in Developing Countries - UNEP Centre, Integrated Environmental and Risk Management and Man/Machine Interaction. The report includes lists of publications, lectures, committees and staff members.

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INTRODUCTION

Hans Larsen,
Head of Department

In 1996 the department expanded its international activities world-wide in the areas of Energy Planning and Industrial Safety. At the same time collaboration with Danish industry, utilities, ministries and governmental agencies has been consolidated.

The department is undertaking research within the following four research programmes:

- Simulation and optimisation of energy systems,
  Hans Ravn
- Energy and environment in developing countries, UNEP Centre
  John M. Christensen
- Integrated environmental and risk management,
  Kurt E. Petersen
- Man/machine interaction.
  Leif Løvborg

The objective of the research is: development of technical-economic optimisation and risk management methods for complex industrial systems and energy systems, with emphasis on environmental considerations and human factors.

About one-third of the department's activities are financed by government appropriations, the remainder by national and international research contracts.

In 1995 a major building activity was initiated with the aim of providing new improved premises for the expanding UNEP Centre, and ultimately assemble the whole department in one building complex. A new building was inaugurated in May by the Executive Director of United Nations Environment Programme (UNEP). Representatives of the Danish Government attended the inauguration seminar. The whole activity will be finalised in 1997.

During the year a new strategy for Risø was prepared and approved by the Board as basis for the research in the years ahead. For the Systems Analysis Department the strategy - in addition to the present four programmes - suggests a new initiative on *Development of scenarios and prognoses for future commercial utilisation of technologies, components, materials etc., including the direct and indirect social consequences.*

By the end of the year the total department staff numbered 58 employees, 41 of whom are scientists or senior scientists, namely, engineers, natural scientists and economists as well as social and behavioural scientists, and 10 are either PhD students at various Danish universities or postdoc fellows. During the year several guest scientists have visited the department for shorter or longer periods. In 1996 one staff member earned a PhD degree.

A significant part of the activities in the department is financially supported by various international organisations or research programmes such as European Union (EU) and UNEP. In addition, the department has undertaken research and development projects together with international organisations such as the Intergovernmental Panel on Climate Change (IPCC), World Energy Council (WEC), the International Association of Energy Economics, the Nordic Council of Ministers and the OECD Halden Reactor Project in Norway.

Simulation and optimisation of energy systems

The aim of the research programme is to develop methods for assessment of energy, environment and economy in relation to long-term energy economic development and to the introduction of new energy technologies into complex energy systems.

In 1996 new simulation tools for analysing combined heat and power systems have been developed using a two-dimensional load duration technique. The study of the feasibility and consequences of introducing large amounts of renewable energy into the electrical power system is being continued, now aiming at a medium time horizon. Organisational aspects of the energy sector are being analysed with respect to the liberalisation of the electrical power sector, where a study on a possible future Northern European power pool is undertaken.

Aspects of the environmental consequences of energy-related activities have been studied. Thus, emission inventories are undertaken, as well as cross-sectoral estimates of greenhouse gas emission reduction potential in Denmark and the associated costs. Further, assessments of externalities from electrical power production based on biogas and off- shore wind

turbines are undertaken as part of the EU project ExternE.

The study of the interplay between the energy sector and the macroeconomic context is continued in a number of projects. Methodological aspects of integrated modelling with detailed representation of the energy sector in a macroenomomic model is analysed, and a model representing Denmark has been finalised.

Energy and environment in developing countries

The programme on Energy and Environment in Developing Countries is hosting the UNEP Collaborating Centre on Energy and Environment and has the overall objective of promoting the integration of sustainable development concerns in energy policy and planning, especially in developing countries. This is done through collaborative activities with institutions at national, regional and international level where research activities focus on development and implementation of methods for the integrated analyses of energy, environment and development issues. An underlying objective of most activities is to support professional and institutional capacity building at national and regional levels in the areas of energy, environment and development planning.

The programme expanded its activities significantly in 1996 especially in the area of methodological development and national capacity building for climate change mitigation analysis through new major projects with the Global Environment Facility (GEF), Danida and other donors. The programme manages or provides technical assistance to official national studies in 15 developing and Eastern European countries.

A major new activity was initiated in the area of environmental and social implications of power sector reform programmes. A collaboration has been established with the government of Ghana, and a joint programme in South-East Asia has been prepared with the Asian Institute of Technology.

Integrated environmental and risk management

The aim of the research programme is to develop methods for analysing the safety and reliability of technical systems and facilitate integrated environmental and risk management taking into account human and organisational aspects.

Major progress was achieved in 1996 on the development of failure analysis methods based on functional systems analysis, partly through the finalising of a PhD study on the identification of hidden failures in process control systems using function-oriented systems analysis, and partly through work on functional analysis used in the design of a control system and a diagnosis system for an autonomous submarine.

The co-operation with the OECD Halden Reactor project was continued focusing on diagnosis support in the form of the development of overview displays in control rooms and analysis of the relationship between component states and control system behaviour.

In 1996 the work on fires in chemical storages was finalised concluding that the laboratory scale experimental facility developed by Risø can provide sufficient information on the mixture of chemical substances in the fire plume for fire risk assessment. This was validated through a series of scaling experiments.

A new activity was launched on the siting of chemical plants and land use planning utilising the results of previous work on risk analysis and accident management.

Man/machine interaction

The aim of the research programme is to develop methods for analysing the interaction between people and advanced technical systems with a view to establishing concepts for safe and efficient execution of complex industrial work tasks.

In 1996 the programme contributed to three European R&D projects: EU-Esprit MATE (Multi-Aircraft Training Environment) in which the department is leading the Human Factors evaluation of training effects of a novel type of training simulator operated via touch-screen input, EU SAFECO (Safety of Shipping in Coastal Waters) in which the department's task is to explore, model and simulate the actions performed by bridge crews in safety-critical ship manoeuvres, and Eureka MEMbrain in which the department is developing a generic framework of a computerised emergency training system.

Under contract with Aerospatiale Avions, Toulouse, experiments in a flight-simulator have been carried out to investigate pilot behaviour during normal and abnormal take-off scenarios.

Two research activities were executed with financial support from the Danish Research Council for the Humanities: the project Supporting Semantic Information Retrieval in Communication Networks by Multi-Media Techniques whose aim is to explore the means of giving industrial product designers smooth access to heterogeneous data bases, and Network in Design, a collaborative effort between researchers on communication and information retrieval within engineering design in Denmark, UK, USA and Canada.

SIMULATION AND OPTIMISATION OF ENERGY SYSTEMS

FORECASTING ENERGY AND ENVIRONMENT

Integrated technical and macroeconomic models

Traditionally, modelling energy and environment involves choosing between two different approaches: a top-down modelling approach based on macroeconomic modelling principles, or a bottom-up modelling approach based on technical descriptions of the energy system. These two approaches have led to very different forecasts especially in the field of forecasting emissions and mitigation costs. Recent studies have argued the need to integrate the approaches as they are more complementary than substitutes. Integrating the two types of models involves making a range of choices concerning which approach to dominate where. In 1996 the department finished the construction of the integrated Hybris model and initiated the rebuilding of the integrated INDUS model.

In a study supported by the Danish Energy Research Programme, two prior existing models — ADAM (Annual Danish Aggregated Model) and BRUS — representing the macroeconomic and technical approaches have been integrated. The integrated model is called Hybris. In the Hybris project elements of the technical-economic simulation model BRUS have been rebuilt and developed further into modules which fit the structure of a macroeconometric model. The new technical modules, describing energy supply and demand, have been integrated into the Danish macroeconometric model ADAM. ADAM is the most widely used macroeconomic forecasting model in Denmark

The use of the integrated Hybris-model is described in the next section.

The Hybris project was carried out from mid-1993 to the start of 1996. The project is continued in a collaboration with the Danish Statistical Office and the National Environmental Research Institute to make an implementation of condensed versions of the energy modules into the official version of the ADAM model.

In 1996 the reconstruction of another integrated Risø-model, INDUS, was initiated. INDUS describes energy consumption and energy-related emissions from the Danish production sectors. The reconstruction of the model takes into account the considerable changes in the industry's energy consumption pattern initiated by the introduction of natural gas.

INDUS is a submodel to the above-mentioned ADAM model. Technical bottom-up analysis and econometric top-down analysis are integrated here. Using input data from ADAM, INDUS forecasts energy consumption and energy-related emissions in 28 Danish production sectors. Most of the relations describing the energy consumption will be formed using econometric estimation techniques. But in some (energy-intensive) sectors, technical knowledge and knowledge of production plans may yield improved forecasts. And in a number of sectors technical analyses may be used to introduce dummy variables into the econometrically determined relations. Combining the two modelling techniques provides better descriptions of the energy consumption.

The new INDUS model will be finished mid-1998. The project is cofinanced by the Danish utilities and The Danish Energy Agency.

The Hybris modelstructure

Work on the Hybris-model was finished in the beginning of 1996. The project involves the rebuilding of modules for the energy supply and demand sectors, using the technical-economic simulation model, BRUS, as a starting point.

The new energy modules are built into the macroeconomic model, ADAM, and a "macrostructure" called Hybris (Hybrid Interactive Simulation) is developed. The bottom-up modules and macroeconomic model "communicate" in an iterative process until convergence is obtained.

The new technical-economic modules consist of:

- A technical description of energy supply technologies. Given energy demand (derived from the ADAM-model), the supply module simulates the power and heat energy supply, calculates the need for new production capacity — and the need for associated investments. Based on actual legislation, prices for electricity and heat are determined. The supply module includes price-driven substitution among fuels. In Hybris the energy supply module substitutes the existing supply relations in the macroeconomic model ADAM.

- A technical-economic description of private energy demand for space heating and electricity use. The module for private electricity use is based on the stock-vintage principles and includes the physical stocks of a number of the most electricity intensive household appliances. The stock of appliances is determined using econometrically estimated relations, which are linked to the macro economic development given by the ADAM model.

Properties of the integrated model relative to bottom-up and top-down models

In general, the combined effect of emission-reducing initiatives are calculated to be considerably lower in the integrated Hybris model than in any of the two models of which it consists. In some cases however, reduction initiatives in Hybris are reinforced by increased energy prices. An example is the effect of increased utilisation of biomass in the energy supply sector. Increasing the use of biomass in the supply sector lowers the emissions of CO_2. But at the same time the increased utilisation of biomass increases the price of electricity, due to higher fuel and investment costs, leading to a lower energy demand in both households and industry, which will result in lower CO_2 - emissions.

The most important properties originating from the integration of top-down and bottom-up approaches in Hybris includes:

- Changing the macroeconomic conditions affects the structure of the energy system. This is true with respect to energy demand, but also — and this is important to the effects in the Hybris model — with respect to energy supply. A changed energy supply feeds back to the economy through changing energy prices and investments.

- Fuel substitution and expansion of capacity in the energy supply sector influence the development of the electricity price and therefore has an effect on energy demand in households and industry.

- Energy price elasticities are relatively low in the top-down relations originating from ADAM and very low in the bottom-up household energy demand modules. The cross elasticities are fairly high in the energy supply module.

Fuel prices are more important in Hybris than in both the macroeconomic model ADAM and traditional bottom-up models, where price effects are almost ignored. The increased effects of prices are caused by the high degree of fuel substitutability in the energy supply module and are primarily connected to the choice of fuel input in electricity generation.

The fuel price elasticity in the energy supply sector is far from holding constant; this makes a differen-

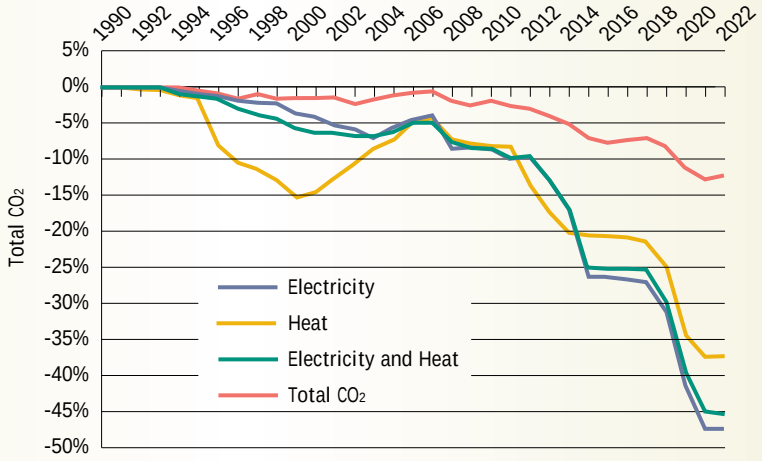


Figure 1.: Changing the energy supply system affects emissions of CO_2

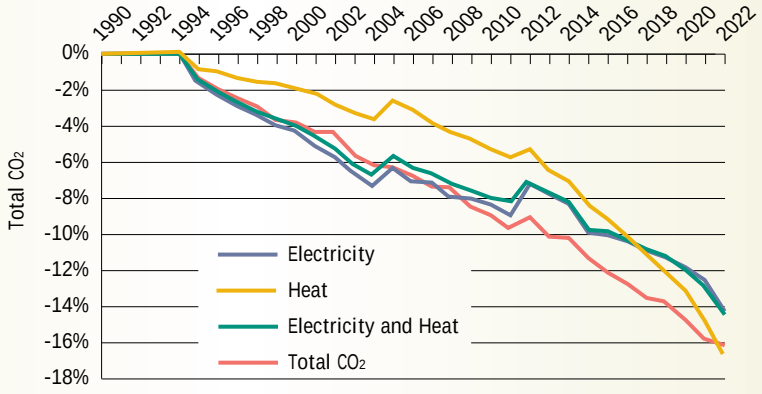


Figure 2.: Decrease in CO_2 emissions as a consequence of slower economic growth.

ce to most macroeconomic modelling of the sector. It is very hard to find econometrically reliable relations for fuel demands in the energy supply sector, and this sometimes forces macroeconomic model builders to leave the possibility of fuel substitution out, and instead to distribute total fuel demand in the sector on fuel types by means of coefficients. In Hybris the possibilities for substitution and the responses to changes in fuel prices have been explicitly modelled. Thus, the modelling of the power sector has been improved relative to the standard macroeconomic modelling.

The Hybris modelstructure does not end the discussion on 'no regret options' in bottom-up energy models, but the macroeconomic implications of energy efficiencies calculated in the very detailed bottom-up model are quantified.

Scenarios performed with the Hybris-modelstructure.

To illustrate some important properties of the combined system consisting of the macroeconomic model and the linked bottom-up energy modules, a number of scenarios are performed with the Hybris-modelstructure. For comparison, a reference scenario has been selected which is consistent with the official macroeconomic forecast for Denmark published in "Finansredegørelse 1995", Ministry of Finance. Among the alternative scenarios analysed are:

- A tax-scenario, where identical CO_2 taxes are introduced for all branches and private households.
- An energy supply scenario, where the energy supply system is gradually changed towards an increased utilisation of renewable energy sources.
- A regulatory scenario, where standards are introduced on appliances and supplemented with other energy conservation measures.
- An economic growth scenario, where the assumptions on trends in economic growth and the development of energy prices are changed.

The environmental consequences of the energy supply scenario are illustrated in Figure 1. The main changes, compared to the reference scenario, are heavily increased utilisations of wind and biomass energy. Substantial CO_2 reductions are achieved within the combined heat and power sector, approximately 10-15% of total energy system CO_2 emissions. In the long run the price of electricity is increased (compared to the reference case), having a minor depressing effect on electricity demand. On the macro-level the scenario leads to an increase in investments, and a minor increase in Gross Domestic Product (GDP) of 0.2% in the long run.
The close relation between economic growth, energy demand and CO_2 emissions is illustrated in Figure 2. The GDP growth rate is reduced by 0.5% p.a., implying a total CO_2 reduction after 30 years of approximately 15% compared to the reference case. An important factor behind this result is that energy demand from industry is described in top-down relations, with long-term production elasticities equal to one. But household energy demand is also sensitive to overall economic growth.

Publication in 1996: 53

Henrik Jacobsen, Poul Erik Morthorst og Lise Nielsen

MODELLING FOR THE ENERGY MARKETS

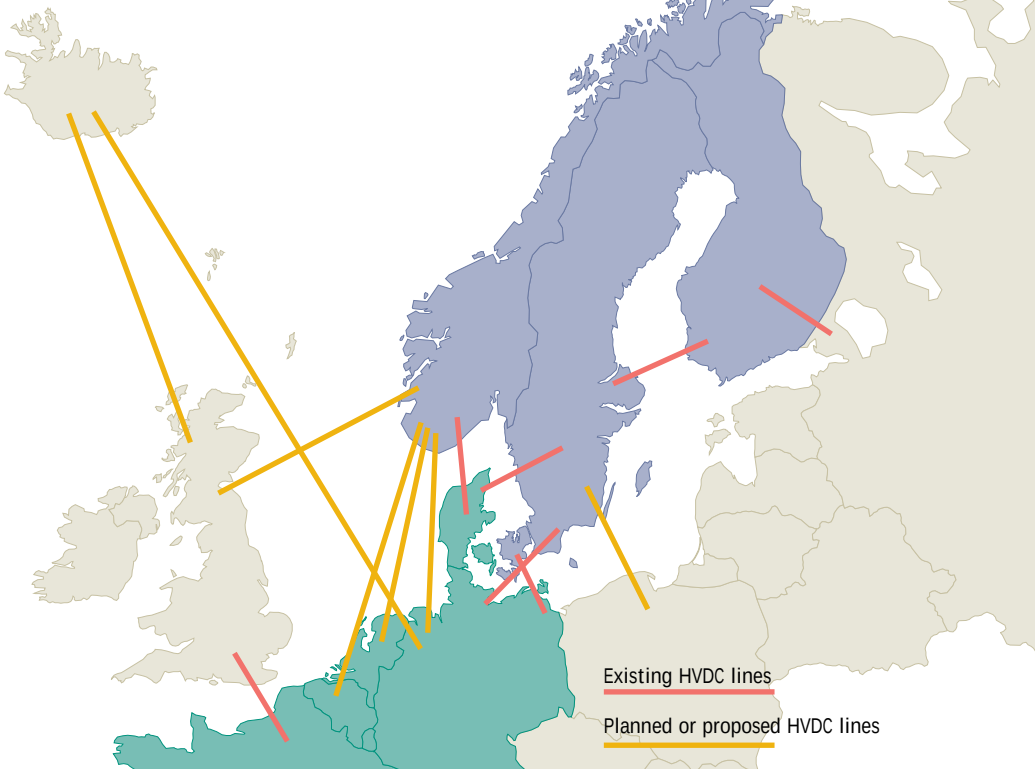


Figure 1.: Existing and future HVDC transmission lines

The development towards deregulated and more competitive energy markets will require new model development and new ways of using traditional models. The last contribution by Risø to the project "Danish utilities in a competitive market" for the Danish Energy Research Programme '93, emphasises the tasks of adapting existing modelling experience to a quantitative analysis of a new organisational framework, and to present an overview and examples of the quantitative methods that are being developed to describe a competitive market for electricity. This project was carried out in collaboration with AKF, Local Governments' Research Institute, and Roskilde University.

The same model approach was used for the "Energy Tariff Project - Latvia", also for the Danish Energy Research Programme and finished in 1996 with a seminar in Riga. The Latvian partners were Institute of Physical Energetics, Latvian Academy of Sciences and Rigas Gaze, the Danish partners were Nellemann, Nielsen and Rauschenberger A/S and Roskilde University.

The most elaborate application of this approach has been presented for a long-term optimisation model focusing on the penetration of energy and emission abatement technologies. Following the project "EURIO - support for energy-environment RTD strategies", which was a project under the EU-JOULE energy research programme, various applications of this type of bottom-up models (EFOM) were presented by Risø at training sessions in Grenoble, France for participants from the New Independent States and Bandar Seri Bagawan, Brunei Darussalam for participants from the ASEAN countries.

However, the most important tools for analysis of the competitive markets are short-term ones, which are able to analyse the causes and effects of price variations, rather than long-term analyses of investment in new equipment.

Electricity in Denmark and the other Nordic countries

The electricity generating system in Denmark lies at the boundary between hydropower in the north and the thermal system in western Europe. The reservoirs in the hydropower system are used for peak shaving for the surrounding thermal system, and the thermal capacity that is available for high and peak load will be used as a reserve to meet the demand in the hydro systems in dry years. Figure 1 shows the different synchronised electricity systems in northern Europe, which are connected by an increasing number of high-voltage direct current (HVDC) cables.

A common Norwegian-Swedish electricity exchange, NordPool ASA, was established by 1 January 1996. Although the pool does not cover the Danish market, the Danish utilities have been very active traders during 1996. Because the last three years have been dry years, there has been a net export from Denmark to the hydro-based systems in Norway and Sweden

Techno-economic models

The techno-economic models that were developed for energy planning and the monopolistic organisation of the electricity supply industry are becoming important tools for the new market organisation by using different assumptions for economic parameters and system limits. A good example is the Norwegian Power Pool Model, focusing on flow into reservoirs and weekly production in a hydro-based system, which has become an important tool for the participants in the Norwegian-Swedish electricity exchange.

In a thermal system the load dispatch among the various electricity generating units can be simulated using models of various complexity with time steps which may vary from few minutes to one year.

In the Unit Commitment-Load Dispatch Model the system is studied for a period of a few days, where heat and power demands are specified for a number of time-steps, e.g. two hours. These models simulate the load

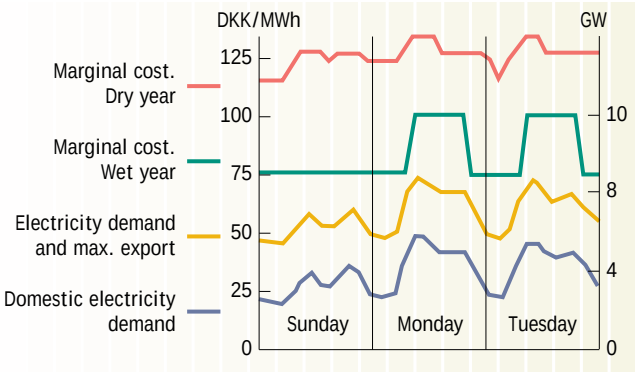


Figure 2. Marginal cost of Danish electricity generation as a function of domestic demand variations and trade with the hydro-based system in northern Scandinavia

dispatch among the available units using various mathematical programming tools.

In the Load Duration Curve-Merit Order Model the load variations of electricity and heat are described using load duration curves for one year divided into seasons.

In the Long-term Optimisation Model the energy supply system is described as a network of energy conversion and transport facilities. Load variations of heat and power are specified as base and peak loads within two seasons. A linear programming problem is set up and solved, e.g. minimising discounted total system cost subject to a set of infrastructural and political constraints.

Modelling few-day periods with different interpretations

In the Unit Commitment-Load Dispatch Model a branch-and bound method is used to solve the non linear mixed integer programming problem. The modelling of the heat and power production is linked by the time-dependent marginal price of electricity at the national power grid. This marginal price must be assumed before the first iteration, e.g. using the price quotations at the electricity exchange in one-hour time-steps in selected typical days. The model, then, calculates the time-dependent marginal price under the current assumptions, which can be used for further iterations.

A well-documented example from 1986 of this model approach has been analysed with different interpretations. The question that was originally studied by the model was whether new condensing capacity that would be required to meet the electricity demand forecast should be nuclear or coal-fired, given the planned structure of the CHP system by 2010. This modelled production structure for power and heat may, however, also represent the Danish CHP systems from the mid-1990s onwards. Some of these market environments include nuclear stations that are located in southern Sweden and northern Germany.

The model calculates a 'system marginal price' on the basis of the demand profile of the few-day period, and information concerning technical data on the installed capacities and the infrastructure of the district heating market.

Very detailed models based on this philosophy have been used by the Danish utilities for more than a decade, both for operational planning for the coming week and for capacity planning. This long-term planning is performed by studying the operation in representative weeks in the future.

For analysts outside the utilities, far simpler versions of the same type of models will be more useful. If the price variations during the next days or a model period in the future under given market conditions are more important for the analyst than load dispatch among the power units, there is no need for the complexity of unit commitment, and the marginal system cost can be derived from load variation and available generating capacity in merit order.

Figure 2 shows the load variations of the Danish electricity demand for a 3-day period around the spring equinox in a model year. The short-term marginal cost of electricity generation from the Danish electricity system is calculated from the variable costs of the different types of power stations in Denmark with their capacities in 1995. In dry years the pool price is assumed to be 300 DKK/MWh, leading to an export demand that is constrained only by the transmission capacity. The similar price in a wet year, when the alternative for the hydro generators is sale to electric boilers, is set at 75 DKK/MWh, leading to import to Denmark. Thus, low marginal generation costs, mainly from CHP stations will give a potential for a significant contribution margin, if exporting to the German market.

A Northern European Electricity Exchange

Such quantitative analyses are being made as part of the work for a new project under the Danish Energy Research Programme, which was started in 1996 in collaboration with Roskilde University. The aim of this project is to describe and analyse the consequences of the Norwegian-Swedish electricity exchange and its alternatives for the Danish electricity and heat supply industry and the Danish targets and measures for energy and environment policy.

Publications in 1996: 31-33, 35-40, 62, 89, 102

Poul Erik Grohnheit

Reduction of Industrial CO_2 Emissions

In recent years Danish energy policy has become increasingly concerned with environmental issues. As a consequence of the reduction target for CO_2 emissions, industrial energy consumption has become a focal point. One of the measures taken to reach the emission target is a CO_2 tax on this consumption, imposed in 1992.

The purpose of a Ph.D. dissertation carried out in the department was to establish a theoretical framework in order to analyse the behaviour of companies, and especially to discuss how energy issues are dealt with in the industrial decision-making process. On the basis of this understanding the dissertation also analyses the existing regulation of industrial CO_2 emissions and assesses their effect on the implementation of energy savings in the companies.

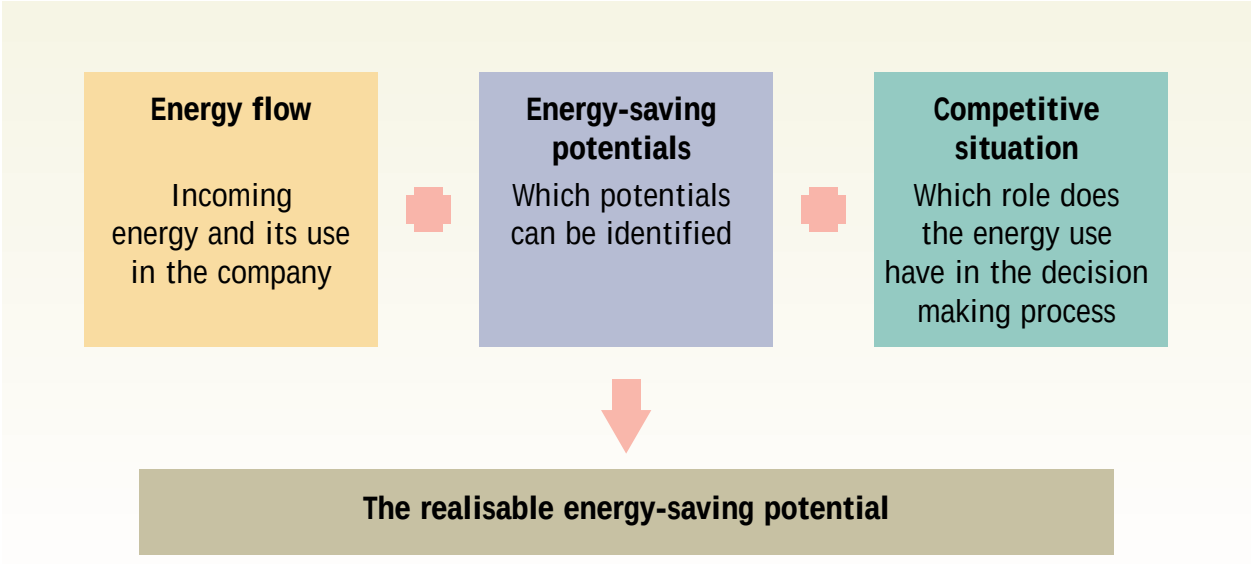
A main issue in the literature about industrial energy consumption has been to explain why companies do not implement all apparently profitable energy savings. Conventional economic theory assumes that the companies would behave in a strictly rational and profit-maximising way.

A concept of rationality that includes more dimensions than the traditional economic one is presented in the dissertation. According to this concept, rational behaviour is the result of processes that aim at functional solutions to given problems. This means that the companies are not striving for optimal solutions in a narrow economic profit seeking-sense, but rather are aiming at optimal solutions in a complex decision-making process. The theoretical discussions are among other things inspired by Herbert Simons' concept of procedural rationality and the evolutionary theory of economic change by Nelson and Winter.

The rationality that influences the actions of companies is therefore in many ways affected by factors within and outside the company.

The company's competitive situation and strategies are key issues in relation to the company's energy use and the possibilities for implementing energy savings or, in broader terms, its behaviour in relation to energy issues. Other important factors that influence the possibilities for implementing energy savings are: the magnitude of energy use, the organisation of production, the use of technology and the general organisation of the company itself.

In particular this applies to investments as a means of implementing energy savings. The fact that



some apparently profitable investments are rejected by some companies suggests that they base their decisions on criteria other than strict economic rationality.

An analysis of the investment decisions in companies suggests that the profitable energy-saving potential and the realisable energy-saving potential are not always compatible. In other words, the energy-saving potential, which can be identified from an economic or technical point of view, is not always identical with the extent of the energy saving potential that is in fact possible to implement - the so-called realisable energy-savings potential.

Case studies relative to this subject were carried out in four different companies. Through a characterisation of different types of companies in relation to the key areas and in relation to their energy use, it was possible to identify the kind of energy savings it would be possible to implement in the different types.

The next step in the dissertation was to analyse the present regulation of the manufacturing industry and to evaluate to which extent the regulation influences the industrial energy consumption. The use of a CO_2 tax on industrial energy consumption is an example of regulation in relation to environmental problems. The focus of the discussion is the use of administrative measures versus regulation through economic instruments such as taxes etc.

An often heard argument in the political debate on CO_2 tax is that a high tax imposed on energy-intensive companies results in loss of jobs because the companies in question will have to close down or move out of the country.

Therefore the CO_2 regulation includes special arrangements for energy-intensive companies. The Danish CO_2 tax is thus divided into a full tax for those with a low energy consumption and an energy audit scheme for energy-intensive companies. This means that these latter companies can get a tax reduction provided that they carry out an energy audit and implement energy savings identified in the audit.

Until now the Danish CO_2 regulation has had only a limited effect on industrial energy consumption. An evaluation of the energy audits carried out in the energy-intensive companies, suggests that the present energy audit arrangement is not the right way to encourage a company to implement all possible energy savings. This is partly because the economic incentives for making the energy audit are significant (due to the tax reduction), but there is little incentive for the company to identify or implement energy savings.

For companies with low energy use the CO_2 tax gives only a very small rise in energy costs and therefore in the total costs. In many cases the company is therefore just paying the extra costs without reducing the energy consumption.

It is therefore seen that for that part of the industry, where the main fraction of industrial energy consumption takes place, the regulation is best performed by administrative instruments and not through economic incentives. At the same time the economic instruments are applied to companies with the lowest sensitivity to price signals. Thus, the findings of the dissertation suggest that the Danish CO_2 tax system is in fact not the most effective way to implement the potential energy savings.

Christina Ingerslev

Simulation Tool for Expansion Planning of Combined Heat and Power

An important element in the planning of future heat and power production systems is the dimensioning of the system, that is, finding the appropriate types and capacities of production plants. The planning problem then consists of obtaining a balance between security of supply and a seldom used reserve capacity.

Traditionally, the dimensioning problem for power-only systems has been analysed by using probabilistic production simulation. In this method the power demand is represented by a probability distribution, and each power plant is represented by its capacity and forced outage rate, i.e. the probability of not being able to produce. This information is combined in the simulation, which gives results regarding the expected production of each power plant and the expected power demand that cannot be met because of failures in the production system.

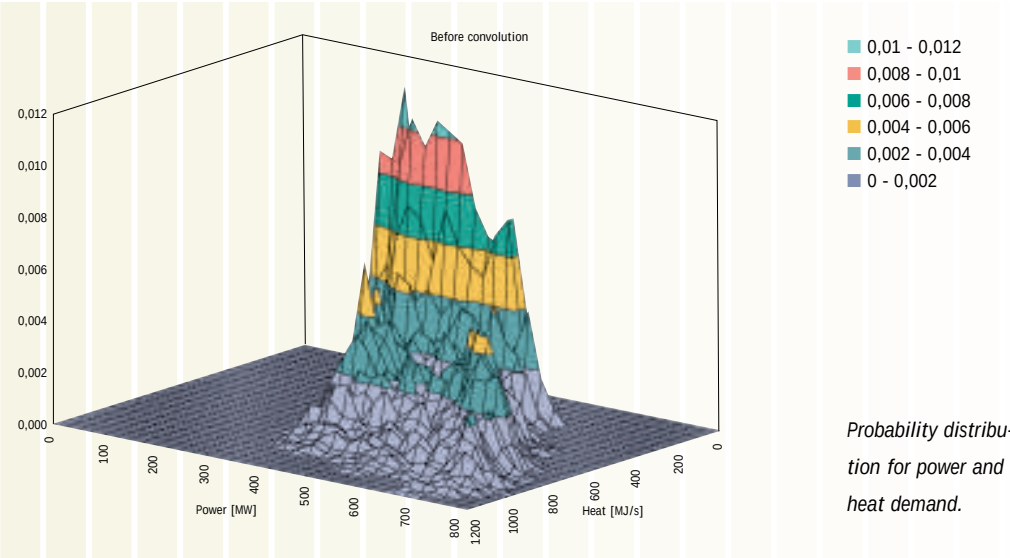
However, due to the large extent of combined heat and power production (CHP) in Denmark, the heat demand has also to be considered when planning the Danish power system. Therefore, in 1996 work has been done to extend the above mentioned traditional method by incorporating the heat. The combined demand is represented by a two-dimensional probability distribution, where the two dimensions are power demand and heat demand. The CHP plants are represented by their power and heat capacities and forced outage rates.

For power-only systems there is a probability of unsatisfied power demand, due to forced outages. Similarly for CHP systems, there is a probability of unsatisfied heat demand. In addendum, an overflow power production may occur, assuming that the heat production has priority over the power production. This is due to the problem of simultaneously satisfying both heat and power demands from the same plants. To study the problem, simulation models have been developed at Risø, which can adequately represent condensing and back-pressure plants, heat-only boilers and in particular extraction plants.

In the models both discrete and continuous representations of the two-dimensional probability distribution for the demand have been introduced, using double Fourier series for the continuous distribution.

An example of a probability distribution for heat and power demand for a period of one year is shown in the figure. By introducing the plants one at a time, taking into account production capacity and probability of failure, the unsatisfied demand is gradually reduced. In this way the final probability distribution for the residual unsatisfied demand is found. This distribution is used to estimate the expected unserved heat and power demands and overflow power production.

By performing simulations for various scenarios with different production plants, it is possible to evaluate balances between security of supply and total installed capacity.



Probability distribution for power and heat demand.

Helge V. Larsen, Halldór Pálsson, Hans Ravn.

EXTERNALITIES RELATED TO POWER PRODUCTION

The European Commission has launched a major study project in collaboration with the US Department of Energy to develop a methodology to quantify externalities. The European side of the project, which has become known as the ExternE project, was the first comprehensive attempt to use a consistent "bottom-up" methodology to evaluate the external costs associated with a wide range of different fuel cycles including fossil fuels, nuclear and renewable energy. Today, this methodology has been successfully developed and reviewed.

A "national implementation phase", was started under the Joule II programme with the purpose of implementing the ExternE methodology in all member states, and in this way to derive comparable data covering the power generation systems of countries for aggregation studies. Also policy studies will be made, demonstrating how such data could feed into the decision- and policy-making process.

To this purpose a network of scientific institutes in all 15 member states except Luxembourg has been established. Moreover Norway participates in the project. The teams involved in the first study are concentrating on the issues of aggregation and policy related case studies, while the new teams, among others Denmark, are concentrating on the implementation of the fuel cycles. The study is using a unified approach, to ensure compatibility between results.

This is being achieved through the use of the ECOSENSE software package, which is an integrated computer system developed at the University of Stuttgart. It assesses the environmental impacts and resulting external costs from electricity generation systems. The system has an environment database at both a local and regional level including population, crops, building materials and forests. The system also incorporates two air transport models, allowing local and regional scale modelling. A set of impact assessment modules, based on the dose-response relationships used in the ExternE Study, and also a database of monetary values are included for different impacts.

Implementation in Denmark

The main objective of the Danish part of the project is to implement the framework for externality evaluation, developed in the ExternE project, for three different power plants located in Denmark, and afterwards to aggregate the study to a national level. The three fuel cycles chosen are fuel cycles for an offshore wind farm, a decentralised CHP plant based on natural gas and a decentralised CHP plant based on biogas. All three kinds of plants are important in the Danish Energy Plan and therefore during the next years these plants are likely to become more and more common in Denmark.

For each of the reference sites the work in 1996 has focused on the assessment of the impacts of the whole fuel cycle with a basis in the ExternE studies of wind, natural gas and biogas. Most of the impacts identified corresponds to those found in the ExternE project with a few exceptions.

Analyse have begun with the identification of the stages of the fuel cycle under assessment. A comprehensive list of burdens and impacts has then been described for each stage. Priority areas for assessment have been identified, based partly on the results of earlier studies but also on the relevance for Denmark.

Impact assessments and valuations are performed using the 'damage function' or 'impact pathway' approach. Methods that are used range from the application of simple statistical relationships, as in the case of occupational health effects, to the use of a series of complex models and databases, as in the cases of acid rain and global warming effects.

A typical impact pathway approach is shown in the figure.

This approach requires a detailed definition of both the fuel cycle and the system within which the fuel cycle operates, with respect to both time and space.

In the ExternE Accounting framework study dose-response functions have been defined for each of the different fuel cycles. These dose-response functions for the different impacts concerning each of the fuel cycles are used directly in this study for Denmark, if they are relevant for the Danish fuel cycle. For new impacts new dose-response functions are made considering similar functions from the ExternE study.

As an example the externalities found for the wind fuel cycle are shown in the following.

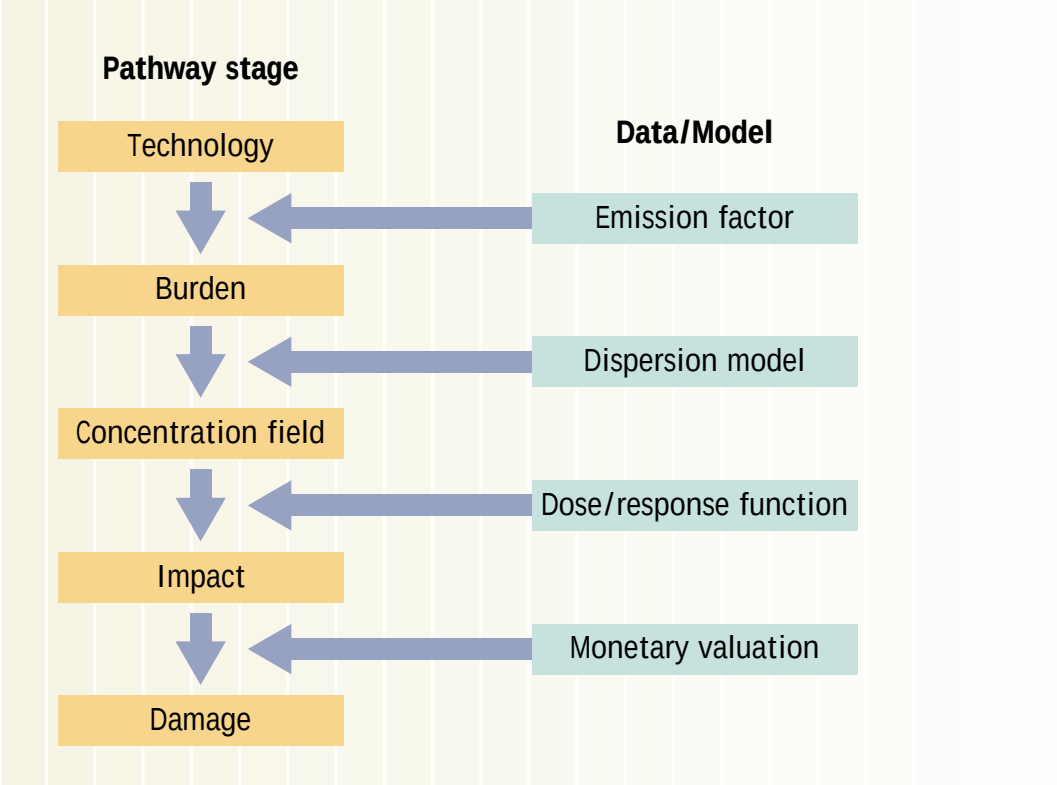


Figure 1.: Typical pathway for impact assessment and valuation

The wind fuel cycle

Tunø Knob offshore wind farm has been selected as a case study for the wind fuel cycle, as investigations concerning environment are already being made. The wind farm is located offshore 6 km east off the coast of Jutland. It has 10 turbines each with a 500-kW capacity and occupies an area at sea of approximately 32 hectares. Tunø Knob wind farm has been in operation since November 1995.

A characteristic of the wind fuel cycle is that there is no chemical pollution connected directly to the operation of the wind turbines. However, there is chemical pollution connected with the manufacture, including the excavation and transportation of materials, and the transmission of the electric energy. In order to include this chemical pollution the wind turbines are considered from a life cycle assessment (LCA) point of view.

For the full life cycle of the wind turbines traditional externalities such as noise, visual amenity, accidents, impacts on birds and impacts of atmospheric emission have been identified. New externalities which have been identified are impacts on fish and interference with electromagnetic communication systems. All the impacts mentioned are regarded as externalities, but not all of them are necessarily quantified or monetised.

An example is the impact on fish. Studies have been made on fish life before and after the establishment of an offshore wind farm. The conclusion of the investigations was that the establishment of an offshore wind farm had no negative effect on fishing in the area. On the other hand the amount of codfish around the fundaments increased. Offshore wind farms have mostly positive impacts on fish, but only very locally, and are therefore monetised to zero.

Some of the impacts identified have already been quantified and monetised. For instance, the impact of noise has been quantified and monetised based on a logarithmic formula, which includes distance from the wind turbine to the residences. The formula is adjusted for the variation between night and day sensitivity, irregular operation, noise sensitivity of people and background noise. Using this formula the annual value of noise from the offshore wind farm is calculated to be 0.07 ECU/MWh.

The three fuel cycles chosen for Denmark are quite different, and the externalities found therefore also vary. For the wind fuel cycle the most important externalities are related to the appearance of the wind farm in the landscape (noise, visual amenity, impacts on birds). For the natural gas fuel cycle emissions from the power production are the most important externalities, while for the biogas fuel cycle the most important externalities are emissions due to transportation of the biogas.

For all three fuel cycles the ECOSENSE model will be used to quantify and monetise impacts related to emissions. For the Tunø Knob wind farm the model will be used for the emissions related to the production of the wind turbines and other materials, taking into account that the associated emissions come from the use of Danish electricity and therefore need to be an aggregated figure for Danish electricity production.

Publication in 1996: 105

Lotte Schleisner

UNEP Support Activities

Energy and Environment in Developing Countries

One of the main functions of the UNEP Collaborating Centre on Energy and Environment is to provide substantive support to UNEP programme activities mainly in the area of energy, but also to some of the activities on climate change under the atmosphere programme and in relation to the UNEP participation as an implementing agency of the Global Environment Facility.

These support activities vary considerably in format from preparing scientific input to official UNEP management presentations at conferences, to working closely with programme staff on strategy, programme and project development, to being responsible for the implementation of major projects like the UNEP/GEF project on "Economics of GHG Limitations".

A few examples have been selected to present the different types of activities and at the same time highlight some of the important events in 1996.

Finalisation of the UNEP Project on "Incorporation of Environmental Considerations in Energy Planning in the People's Republic of China"

The recently completed China study represents one of the larger activities of UNEP's energy programme in recent years. The project aimed specifically to strengthen national and regional institutional capacity in the area of energy environmental analysis and to promote policies that would reduce energy-related environmental emissions.

The role of the UNEP Collaborating Centre (UCC) in this project was mainly to support the substantive work undertaken by the involved Chinese institutions - the National Environment Protection Agency (NEPA) and the Energy Research Institute (ERI) - through formal and informal training, and close collaboration on the use of energy-environment analysis methods and modelling tools. In addition the UCC supported the general UNEP monitoring and supervision of the project.

The Chinese project team arrived at a number of key policy recommendations for changing the present pattern of energy production and consumption, and establishing an energy system which is more compatible with a path of sustainable development. These policy recommendations include the following:

The Akosombo power plant in Ghana

- Changes in the energy production mix - especially increasing the provision of high-quality energy
- Promotion of clean-coal production and consumption technologies
- Improvements in energy efficiency
- Introduction of integrated energy-environment planning
- Introduction of environmental regulations and economic instruments which facilitate the implementation of an environmentally friendly energy strategy
- Strengthening of international co-operation and transfer of technology.

The Chinese institutions are continuing the analytical work based on the enhanced capacity. The above recommendations are being promoted in the policy making process. In addition it is still under discussion to develop some specific projects for funding, e.g. by the Global Environment Facility based on the outcome of the project.

World Solar Summit

Under the auspices of the World Solar Summit Process (WSSP) UNESCO has since 1993 undertaken a large number of regional meetings promoting the use of renewable energy sources. In addition a high level World Solar Commission has been established under the Chairmanship of President Mugabe of Zimbabwe. The WSSP culminated in 1996 with the World Solar Summit in Harare where a large number of representatives from governments and UN organisations met to discuss a joint declaration and a work programme for what was termed a "Solar Decade" .

These documents - the Harare Declaration on Solar Energy and Sustainable Development and the World Solar Programme 1996 - 2005 - had been prepared by UNESCO with an inter- agency consultation process where UNEP had been involved through the Centre. The Centre also prepared the substantive input for the UNEP address to the Summit and in addition Centre staff participated in the UNEP delegation at the Summit.

In the follow-up process to the Summit UNEP has indicated its willingness to examine the work programme and where possible to help in disseminating information and mobilizing funds for specific renewable project concepts included in the World Solar Programme.

Workshop on Valuation of Environmental Externalities

In its core agreement with UNEP and Danida the Centre has been provided with some limited funds to initiate UNEP and Centre programme support activities in the form of research projects in developing countries, organisation of meetings and workshops, etc.

One of the activities funded in 1996 was a two day expert workshop in June on the valuation of environmental externalities and the use of this information for policy purposes in developing countries. The workshop was hosted by the Centre and integrated in its work programme on methodological issues. The meeting was attended by participants from Argentina, India, Mexico, Thailand as well as representatives from UNEP's Economics programme, the EU and Danida.

The workshop focused on, how to assess and valuate environmental externalities associated with specific energy systems in developing countri-

es, and possibilities for adapting methods already developed and used in industrialised countries. The integration of this information into the policy process was also addressed.

The workshop identified the need for capacity building as a crucial issue for any future application of externality assessment in developing countries and it was generally agreed that while existing methods provided an important foundation, any developing country applications would require significant development and adaptation of the approaches used in industrialised countries. The participating institutions found that a specific initiative in this area was required and the Centre was subsequently asked to coordinate a joint initiative for a new work programme with case studies in Asia and Latin America for EU funding. A proposal will be submitted early in 1997.

Support to UNEP Programme Formulation

UNEP management decided from the beginning of the year to formally place the responsibility for all energy activities under the Director of the Industry and Environment Office (IE) in Paris and integrate energy in the overall UNEP Subprogramme on sustainable production and consumption. The policy and strategy discussions for the energy work programme were therefore finalised during the year combining the general mandate in the area of energy with the existing strengths of the IE office and the Centre.

The convening themes for the new programme are

- Promotion of energy efficient technologies and policies, and low impact energy sources
- Development and dissemination of methodologies and tools for incorporating environmental concerns into energy sector planning and policy
- Assessment of environmental and social implications of energy sector reform programmes

Within these themes focus will be on catalysing action in line with UNEP's general mandate. IE and Centre staff have been working closely together on the preparation of the programme and the specific activities.

Similarly the Centre has been involved in supporting the development of both specific projects and the future work programme on climate change for UNEP's participation in the GEF. An internal GEF task force has been formed in IE with Centre staff participation, and joint project proposals are under development reflecting the convening themes outlined above.

Centre staff has also worked directly with the GEF Coordination office within UNEP on reviews of, for example, project proposals from other agencies, draft strategy papers for operational guidance and documents from the Scientific and Technical Advisory Panel. In addition the Centre has contributed to a number of the Enabling Activity proposals that UNEP, as a new activity, prepared during 1996 for countries in Africa.

Publications in 1996: 11, 81, 127.

John M Christensen, Pramod Deo

CLIMATE CHANGE MITIGATION: COUNTRY STUDIES AND CAPACITY BUILDING

The United Nations Framework Convention on Climate Change (UNFCCC), now ratified by over 150 countries, aims at limiting the concentration of greenhouse gases in the atmosphere to a level that will minimise serious impacts. While it is recognised in the convention that the industrialised those with economies in transition nevertheless have commitments under the convention. These consist of reporting on the amount of emissions, and on the measures that can be taken to reduce these emissions and adapt to climate change impacts. Such reporting requires considerable analytical and institutional capacity in the countries concerned, and the convention provides for assistance to countries to establish these capabilities. The Global Environment Facility (GEF), which is the financial mechanism set up to support the implementation of the global environmental conventions, supports such "Enabling Activities", and similar funding is provided by national agencies like those of Denmark (Danida), Germany (GTZ) and the United States.

The UNEP Centre is engaged in a large number of capacity-building programmes for climate change mitigation analysis, through the UNEP/GEF project "Economics of Greenhouse Gas Limitations" and through parallel activities funded by Danida and the United Nations Development Programme (UNDP). The country studies carried out under these projects have the triple purpose of producing mitigation analysis reports, establishing capacity in the countries for carrying out such work, and testing and refining the methodological framework.

Fifteen countries are taking part in the current programme of national mitigation studies coordinated by the UNEP Centre. The UNEP/GEF project comprises Argentina, Ecuador, Estonia, Hungary, Indonesia, Mauritius, Senegal, and Vietnam; Danida supports three countries in Southern Africa (Botswana, Tanzania and Zambia) as well as Peru; and UNDP/GEF funding is providing support for Egypt, Jordan and Uruguay.

Two workshops were held in Denmark in June and August 1996 bringing together the national project coordinators and the country technical teams, respectively. At the one-week August workshop, teams received training in the mitigation analysis methodology. At the same time contractual arrangements with most of the countries were completed, allowing in-country work to commence by September 1996.

The start of national project work was marked in each country by a workshop, attended by one or more UNEP Centre staff. In addition to the national teams responsible for carrying out the studies, national workshops brought together representatives from ministries, organisations, industries and utilities who had been identified as "stakeholders" within the national climate change context. The main aims of the two- to three-day national workshops were to establish awareness of the national mitigation analysis study among stakeholders, and to discuss in detail issues, methodologies and work schedules specific to the country.

A particularly important topic for discussion, involving qualified input from a wide range of different representatives, was the establishment of the long-term baseline scenario for the country. This scenario represents the reference against which efforts to reduce the increase of greenhouse gas emissions have to be evaluated. Thus the analysis requires a 20-30 year vision for economic, social and industrial development, consistent with, but going beyond the normal time horizon of, official government planning.

Charcoal, produced in rural areas in Zambia, is both consumed locally and transported over long distances to urban centres where it supplies most cooking fuel needs.

The fifteen countries involved in the study programme span a wide range of geographical, developmental and physical settings. Some countries, such as Argentina, Egypt, Tanzania and Zambia, have already carried out in-depth greenhouse gas inventory and abatement studies, and the present activity involves an extension to other sectors and gases, or a more detailed examination of the options. For some participating countries, such as Estonia, Jordan, Mauritius and Vietnam, the activity represents the first mitigation study and analytical capacity has to be established.

Mauritius is one of the countries

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Participants at the first national workshop in Mauritius held in November 1996.

taking part in the UNEP/GEF project "Economics of Greenhouse Gas Limitations". Although contributing an insignificant global share of anthropogenic greenhouse gases to the atmosphere, Mauritius is highly vulnerable to climate change impacts. As a small island state in the Indian Ocean, Mauritius suffers considerable damage at regular intervals from cyclones, and serious coastal erosion is already evident. This vulnerability and a high level of environmental awareness contributed to Mauritius being the first country to ratify the UNFCCC.

In spite of the relatively small contribution of Mauritius to global GHG emissions, the country does have a potential to reduce emissions, particularly of CO_2 from the burning of fossil fuels. Currently oil-fired power stations supply electricity to most of the island's consumers, apart from the sugar factories. The latter produce their own power from burning bagasse (crushed sugar-cane refuse) which has zero net emission of CO_2 because of the absorption of CO_2 by biomass during its lifetime. A potential mitigation option for Mauritius would be to increase the amount of electricity generated by bagasse, displacing fuel oil and thus decreasing net CO_2 emissions. Implementation of this option would require a considerable investment in advanced technologies, as well as overcoming institutional barriers. In addition the future market for sugar is uncertain. All these factors enter into the analysis, along with other mitigation options such as the use of alternative transport fuels.

In contrast, Zambia is a landlocked relatively sparsely populated country with one of the highest degrees of urbanisation in Africa, which leads to a high consumption of charcoal for cooking purposes, associated with serious local deforestation for charcoal production and transport of the fuel over distances as great as 200 km. Several options to address charcoal as an urban household fuel exist, including improved methods of production and combustion, substitution by coal briquettes and electrification of houses. Adoption of these alternatives would have various consequences, both negative and positive, as well as reducing net CO_2 emissions. The country possesses at the same time a surplus of hydropower capacity and is well placed geographically to contribute both to the generation and transmission of power to a regional power pool. The mitigation study being carried out by the Centre for Energy, Environment and Engineering (Zambia) is exploring these and other options using integrated energy modelling and following the methodological framework set out in the UNEP/GEF project.

The remaining thirteen countries also have their peculiarities, potential options and challenges. UNEP Centre staff are working closely with the national teams in each case to apply the methodological framework for mitigation analysis. The national studies are scheduled to be completed in early 1998. Further workshops are planned throughout the project period, both in the respective countries, in regional centres and at Risø. Country team members will also visit Risø for extended periods to work closely with UNEP Centre staff. This cooperation was begun already in 1996 with the visit by a member of the Zambian study team.

Gordon A. Mackenzie, Pramod Deo, Arturo Villavicencio, Robert Redlinger, Henrik Meyer

Climate Change Related Activities in Burkina Faso

Since February 1995 the Centre has been responsible for a Danida-supported national capacity building programme in Burkina Faso. The project has been aiming to assist the Burkina Faso Government in building sufficient indigenous capacity to establish the initial reporting to the United Nations Framework Convention on Climate Change, which the country ratified on 2 September 1993.

Under the Ministry of Environment and Water in Ouagadougou an interministerial climate change unit, called C.I.M.A.C, has been set up. It consists of members from all the ministries who are concerned with climate change problems.

The main activities in 1996 have concentrated on collecting data and calculating a preliminary inventory of greenhouse gases. The final report was presented and discussed on a workshop held in Ougadougou 14-15 January 1997. About 50 representatives from all the ministries and institutions concerned with climate change were present. The total emission of CO_2 from the combustion of fossil fuels is about 550 thousand tonnes. With about 9.5 million inhabitants this equals 0.06 ton/capita. This is 57 times lower than the global average and about 200 times lower than Danish emissions. There is therefore plenty of room for an increase of the CO_2 emissions from Burkina Faso before the country reaches a long-term sustainable global emission target of about 1 ton/capita if other emissions are omitted. In order to create development an increase in energy consumption is needed. The problem comes to how to increase energy consumption in a way people can afford. The total energy consumption in Burkina Faso is about 50 PJ, and 80% of that is covered by fuelwood.

Afforestation due to population pressure on natural resources, resulting among others in land clearing for agriculture, is the main reason for deforestation. In order to supply the population with the necessary fuelwood the new option of local management of forest and tree resources by local villages has shown promising results. Hereby the CO_2 emissions of about 6300 thousand tonnes from deforestation could also be reduced.

Only about 3% of the population has access to electricity which is produced from oil. To extend the central electric grid to most rural households will be prohibitively expensive. A new option is now ready for rural areas, however. A typical solar photovoltaic system of 50 Watt can supply a household with electric light and electricity for a TV and radio, a regulator will shut the system off if the load is too high. The annual cost is now not much higher than what many households spend on kerosene candles and batteries. The problem is the high investment cost and the lack of credits for potential buyers.

Preliminary calculations of emissions of CH_4 and N_2O were also made. One of the interesting results of the project is that the emissions from savanna fires been have shown to be important. The preliminary data of 20 million hectares burned annually gives a value of 45 thousand tonnes of CH_4 , which is equivalent to twice the CO_2 emissions from fossil fuels. The savanna is burned each year for many purposes, but it is damaging to the trees etc. It is interesting to observe that the energy content of the burned straw is about 350 PJ or seven times larger the present energy consumption, so here is a potential energy source not yet used in Africa. A collaborating effort with the Institute of Geography on remote sensing of savanna fires is continuing, and has now by the method of fire-scar observation found reasonable values for the number of fires in Burkina Faso. This activity is part of a joint effort between UCCEE and a series of institutes at the University of Copenhagen: Geography, Plant Ecology, General Microbiology, Population Biology and the Zoological and Botanical Museums, a four year project financed by the Danish Council for Development Research. Risø is participating in the part of the project covering macroscale analysis of the distribution in time and space of fire, of emissions of greenhouse gases and of natural and human controls of fire distribution.

Training session at Risø

Jørgen Fenhann & Arturo Villavicenio

Risø-R-959(EN)

POWER SECTOR REFORMS IN DEVELOPING COUNTRIES

Over the past several years, pressure has been increasing throughout the world for fundamental changes to the structure of the electric power sector. Once regarded as a natural monopoly and a critical "national security" sector best suited for state ownership, the power sector has been undergoing a transformation under which the new watchwords have become unbundling. deregulation and privatization.

These trends toward privatization and increased competition are not confined merely to industrialized countries such as the UK, USA, Norway and Sweden. Spurred on by the World Bank and the International Monetary Fund, many developing countries are in the process of fundamental economic reform entailing significantly increased private sector participation in previously state-run activities, including electric power.

Restructuring of the electric power sector can take different forms, varying both in terms of degree of private sector participation and in terms of degree of unbundling (splitting vertical-integrated monopolies into separate generation, transmission and distribution entities). In some countries, the government-owned monopoly structure has been fundamentally maintained, but private independent power producers (IPPs) have been invited to construct new power plants and sell their power to the state monopoly. This has been the basic approach of many Southeast Asian countries, including Malaysia, the Philippines and Thailand. Other countries have taken a more radical approach, choosing to dismantle the state monopoly and move toward complete privatization and unbundling. Chile and Argentina may be the primary exponents of this model.

Regardless of the model used, the fundamental objective of electric power sector restructuring has been the same in all countries: to improve the efficiency of electricity provision, utility financial performance and service. However, power sector reform can also have other unintended consequences not always envisioned by the promoters of reform. Environmental considerations and social equity issues are two areas in which side-effects of power sector reform may be particularly significant.

UCCEE collaboration with Ministry of Mines & Energy (Ghana) on Power Sector Reform

As part of its work programme for 1996-1997, the UCCEE is undertaking to study the environmental and social implications of electric power sector restructuring and to develop methods to improve the outcomes, particularly in developing countries. In pursuance of this programme objective, UCCEE is collaborating with the Ministry of Mines and Energy in Ghana in its Power Sector Reform.

The power sector in Ghana is partially vertically integrated. Power is generated and transmitted by one state-owned company and distributed by two state-owned companies. The reform in the power sector envisages the separation of the generation and transmission functions, and a competitive generation segment of the industry. The transmission system will be a limited liability company and the country will be divided into power distribution concession areas and will allow private sector participation. The transmission and distribution segments of the industry will be regulated under a more transparent and incentive-based regulatory process.

It is in the context of this proposed structure that the Ministry of Mines and Energy in Ghana and the UNEP Centre have agreed to collaborate in the following three areas: (i) to document the Power Sector Reform process in Ghana with the aim of sharing that experience with other countries in the region; (ii) to participate in the work of a Task Force set up by the Ministry to look at regulatory issues for the power sector as well as customer services issues, and (iii) to conduct a study on the environmental and social implications of restructuring the electric power sector.

1 Documenting the Power Sector Reform Process

The objective here is to help the Power Reform Committee document the entire reform process with the view of sharing this experience with other countries in sub-Saharan Africa which are considering or in an early stage of reforming their power sectors. The Centre has reviewed the proposed structure of the report submitted by the Power Sector Reform Committee and made some suggestions to the committee on what should go into the report. In pursuing the objective of sharing Ghana's experience with other countries in the region, the Centre is collaborating with the African Energy Policy Research Network (AFREPREN) in Nairobi, Kenya to organize a workshop to share this experience.

2 Task Force on Regulatory and Customer Services Issues

The main contribution of the Centre to the task force's work was a direct participation in an intensive four-week work programme which focused on Customer Services Issues of the regulatory framework. The work involved the review of different countries' experiences in customer services issues, and also how the electric utilities in Ghana have approached customer services issues. The Task Force, in the first draft of its report, made recommendations in the following areas:

- Quality of Power Supply, which proposed standards for the maximum number of power outages a year, range for voltage fluctuations and their associated penalties for non-compliance.
- Quality of Rural Power Supply
- Quality of Services: under this, recommendations were made on Power Connection and Metering, Meter Reading, Customer Indebtedness and Debt Collection, Power Disconnection and Reconnection and Customer Protection. Regarding Dispute Handling Process between the utilities and their customers, a procedure was proposed for dispute resolution.
- Safety Issues as regards customers of the electric utilities.

This report has been submitted to the Power Sector Reform Committee for its comments.

3 Study of Environmental and Social Implications of Electric Power Sector Restructuring

The industry structure envisaged will lead to a movement from an essentially hydro-based power generation system to a mix of hydro- and thermal- based systems. The introduction of fossil fuel-based generation has its environmental ramifications with which the country has no experience in dealing. Furthermore, the restructured electric power industry will inevitably lead to rate increases as current rates are considered low. This raises the issue of making power accessible and available and affordable to low income people in urban areas as well as the rural communities.

The study primarily aims at assessing the environmental and social implications of the reforms in the power sector. It is also looking at the institutional interaction between two regulatory bodies - the Environmental Protection Agency and the Electric Utility regulatory body. The study is being undertaken in collaboration with a local organization - the Kumasi Institute of Technology, Energy & Environment (KITE).

Publication in 1996: 127

John Turkson

ECONOMICS OF GREENHOUSE GAS LIMITATIONS - METHODOLOGICAL GUIDELINES

Developing and industrialised countries are currently preparing national communications to satisfy their commitments as signatories of the United Nations Framework Convention on Climate Change (FCCC). As part of these requirements countries are encouraged to assess their climate change mitigation potential. The purpose of these assessments is three fold: 1) to project future greenhouse gas emissions, with and without measures to abate greenhouse gas emissions, 2) to assess the potential to reduce emissions, and 3) estimate the additional cost required to abate these emissions. UCCEE is developing methodological guidelines for these assessments in the project Economics of Greenhouse Gas Limitations sponsored by the Global Environmental Facility GEF). This project, which was initiated in 1996, consists of two main elements the development of methodological guidelines and their application in eight national and two regional studies. The UCCEE has as one of its major partners on this project the Lawrence Berkeley National Laboratory (LBNL), California.

The methodological guidelines are a refinement of the methodological framework of the earlier UCCEE project UNEP National Greenhouse Gas Abatement Costing Studies. This project focused on the assessment of CO_2 reduction costs for the energy sector. An important goal of the new GEF project is to expand this framework in order to compare greenhouse gas reduction options in the energy sector, industry, forestry, agriculture and waste management, on a common basis. The primary greenhouse gases considered will be CO_2, CH_4 and N_2O.

The project is the leading international one in the development of methodological guidelines for the economic assessment of mitigation options.

Main concepts and definitions

The methodological guidelines include a definition of main economic and technical concepts, a common analytical structure for the country studies, and a number of key technical and economic input assumptions. The analytical framework is purposely defined in a broad manner to allow countries to use different models and scenario construction tools in a consistent assessment of mitigation options for the most important national greenhouse gas emission sources. The methodology is established on the basis of cost-benefit analysis, partial equilibrium modelling at sector level, and macroeconomic assessment. The coverage and sophistication of the applied methodologies in the country studies vary according to available data and models and to already established capacity for climate change assessments. This implies that some country studies focus on the assessment of a limited number of greenhouse gas emission reduction options in the energy and the forestry sector supplemented with a broader qualitative discussion of sectoral and macroeconomic impacts while other countries conduct more comprehensive modelling activities.

The country studies are asked to provide a number of common outputs including:

- establishment of a baseline and a mitigation scenario for a short- to medium time frame until 2005/10 and a longer time frame until 2030/40.
- cost assessment for reduction ranges between 10% and 25% emission reduction from the future baseline in 2005/10 and between 30% and 50% reductions in 2030/40.
- mitigation cost assessed at the individual project level, sector level, and as far as possible macroeconomic level.

The more formalised country study elements will be supplemented with an assessment of broader social, environmental and political impacts of the implementation of climate change mitigation strategies.

New methodological development areas

The overall aim of the analysis is to assess the impacts of implementing mitigation projects or strategies that have a positive impact on reducing global climate change. Mitigation projects or strategies will have a large number of different impacts including economic, and social and environmental impacts. Some of these impacts

are traditionally measured as economic impacts while others, for example environmental impacts, in some cases are measured as damage costs and in other cases measured as physical loads. Economic impacts will be assessed in monetary units implying that specific weights in the form of prices are going to be assign-ed to the different impacts. These weights can, for example, be market prices or monetary estimates of environmental externalities. Physical environmental impacts can be measured in a large number of different units - these impacts will by nature not be directly comparable with the monet-ary impact assessments. Some main methodologies for assessing such market and non-market impacts are described in Table 1.

Climate change mitigation assessment in principle involves a comparison of market costs- and benefits and the long-term benefits of reduced climate change. The assessment of benefits of reduced climate change is by nature difficult and uncertain. The benefits of reduced climate change, given a number of assumptions, can be assumed to be proportional to GHG emission reductions at given points in time. In this simplified case the cost-benefit analysis can be conducted as a cost-effectiveness analysis (defined in Table 1) where the costs of meeting alternative emission reduction targets are assessed. This is a reasonable assumption because climate change is a global environmental problem where there is no direct link between a country's greenhouse gas emissions and the national impacts of climate change.

The economic impacts of implementing a climate change mitigation project will imply that the society gives up alternative resource use and final consumption. The "value" of these sacrifices depends on the supply and demand in the related factor and final goods markets. A full assessment of all such impacts is very complicated especially if non-marginal changes in factor markets or final consumption are generated. The methodological framework defines how these impacts can be assessed at project-, sector and macroeconomic levels and outlines how different methdologies and modelling tools can be used in a consistent way.

The assessment at project level considers an individual project assuming that this project is a stand-alone implementation. The project assessment also assumes that the project is small and marginal implying that the implementation creates no changes in factor prices or final product prices. The assessment at sector level considers a case where a number of mitigation projects are implemented in one specific sector. Technical interdependencies between projects in that sector and impacts on production inputs and final products of that sector are to be included, but the macroeconomic development and other economic sectors are assumed exogenous. The macroeconomic assessment, finally, considers the full socio-economic impacts of implementing mitigation strategies in one or more sectors, together with the interaction of the different sectors and the economy.

The integration of project, sector and macroeconomic assessments is a new international research area. Consequently part of the project activity is the testing of the potential interfaces between different sector models for energy, forestry, and agriculture and macroeconomic models.

Table 1 Methodologies for the assessment of economic impacts of climate change mitigation

Traditional cost benefit analysis
The basic idea is to measure all negative and positive project impacts in the form of monetary costs and benefits. Market prices are used as the basic valuation as long as markets can be assumed to reflect "real" resource scarcities. In other cases it is recommended that shadow prices be used. These are meant to reflect prices that would occur in a "perfect" market.

Cost effectiveness analysis
A special sort of cost benefit analysis where all costs of a portfolio of projects are assessed in relation to a policy goal. The policy goal in this case represents the benefits of the projects. The policy goal can for example be a specified goal of emission reductions for GHGs and other emissions resulting in an output expressed as $/ton of GHG emission reduction. The benefits of the policy goal will not be assessed in the cost effectiveness analysis.

Multicriteria analysis
The basic idea of the multicriteria analysis is to define a framework for integrating different decision parameters and values in a quantitative analysis without assigning monetary values to all parameters. Examples of parameters that can be controversial and very difficult to measure in monetary values are human health impacts, equity, and irreversible environmental damages.

One of the key problems in the integrated sectoral assessment is to make energy- and forestry modelling consistent. Mitigation measures in the forestry sector are qualitatively diffe-

rent from those in the energy sector because forests are both sources of and sinks for carbon. In addition, forestry measures can be used to offset conventional greenhouse emissions by substituting biomass fuels for oil, coal and gas and by switching from energy-intensive building materials, such as aluminium and steel, to wood. There are a number of other problems that make it hard to compare greenhouse gas mitigation measures in the two sectors. For example, trees do not sequester carbon at a constant rate and this rate is sometimes discontinuous over the life cycle of the carbon stored in biomass. Also, most carbon sequestration programs are, by nature, temporary since it is impossible to continually expand forested areas. In addition, the opportunity cost of the land used to sequester carbon is often hard to compute. Finally, it is very hard to predict the land use patterns over time that will influence the carbon sequestration potential in a country. For these reasons, special accounting procedures have to be developed to compare the costs and mitigation potentials of emission abatement measures in the forest sector with those in other sectors.

Another new methodological area is macroeconomic assessment. Climate change mitigation is expected to address key economic priority sectors in the developing countries such as energy, industry, forestry and agriculture. The implementation of mitigation projects will demand scarce capital and foreign exchange resources and can also lead to increased production costs. It is therefore important to identify areas where project implementation can be combined with priority investment programmes in such a way that production efficiency of the sectors as far as possible is increased. Traditional macroeconomic models do not reflect the specific context of the economics of climate change mitigation in developing countries, and the project therefore develops a simplified model that specifically applies to existing data and analytical capability in the countries. The model will link up to national sectoral projections and input-output statistics.

Work programme

The methodological guidelines are being developed in an iterative process, where the core project team produces guideline materials which are discussed at project workshops and tested in country studies. The guideline materials comprise definitions and concepts, data and assumptions, as well as broader methodological discussion papers. The guideline materials have been presented and critically reviewed at a project managers workshop in June, at a country team training workshop in August and at national workshops in October, November and December.

The guidelines are also a key input in establishing Mitigation and adaptation cost guidelines by the Intergovernmental Panel on Climate Change (IPCC). John Christensen from UCCEE together with Lawrence Berkeley National Laboratory is leading the development of an IPCC Discussion Paper on the mitigation and adaptation costing issues that most likely will lead up to more official IPCC guidelines in this area. Under the auspices of UCCEE Risø is through UCCEE hosting an IPCC workshop in June 97 to review the costing paper.

Publications in 1996: 13, 44, 45, 50, 51, 79, 80, 125

Kirsten Halsnæs, John M. Callaway, Henrik Meyer

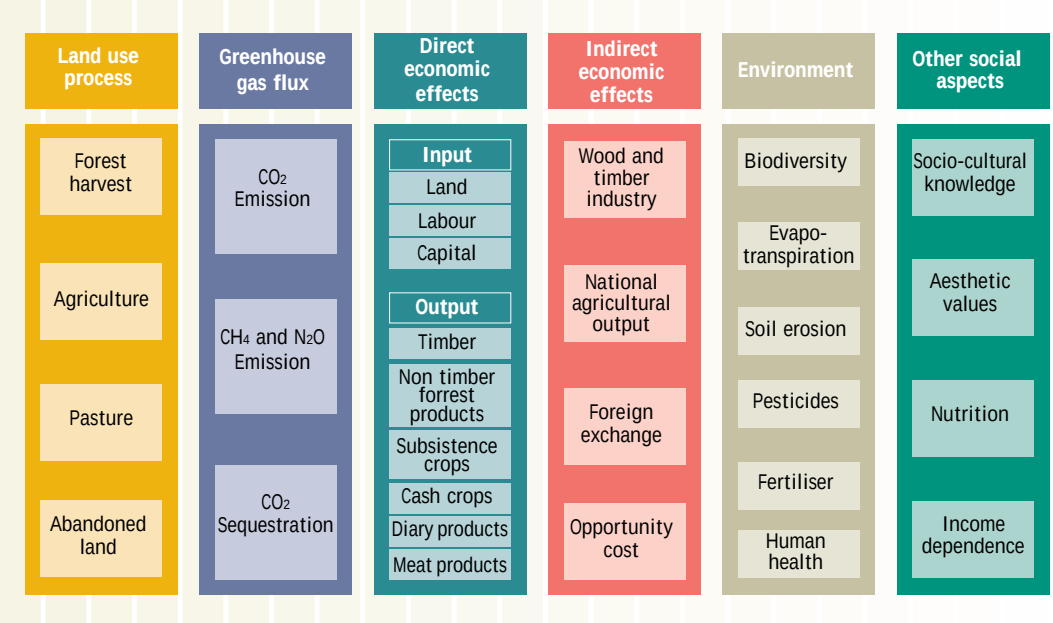
Climate Change Mitigation and Land Use in Developing Countries

A methodological framework for assessing the economic and environmental impacts in relation to climate change mitigation and land use in developing countries, is undertaken as a PhD project at the UCCEE. The project was initiated in February 1995, in association with the Department of Social Science at Roskilde University.

Climate change mitigation in relation to land use is a subject that in spite of its significance, has been granted relatively sparse attention. In this light, the study is relevant as a part of the methodology development ongoing at the UCCEE. Being a participating country in the project "Economics of Greenhouse Gas Limitations" supported by the Global Environmental Facility, Ecuador has been selected as a case study country for application of the methodological framework.

Land use change in many developing countries rotates between deforestation, agricultural crop production, cattle pasture and abandoned land. The figure presents the elements of the physical and economic analyses of climate change mitigation in relation to a particular land use pattern. That pattern embodies the foundation of a baseline scenario. The project aims to assess the difference between a baseline and various mitigation scenarios presented by the following land use options:

- Protection of existing primary forests.
- Reforestation projects.
- Implementation of agroforestry.



These mitigation scenarios contain, in addition to climate change mitigation benefits, various associated development gains and environmental services.

During 1996 a screening has been assessed on climate change mitigation options in relation to land use in Ecuador. The analysis is elaborated in a specific local area as a case study. The different land use options are compared on hectare basis. An inventory of the carbon content from the different land use practices is assessed using spreadsheet models. Economic analysis and qualitative environmental analysis are both used as tools in constructing baseline and mitigation scenarios from 1995 to 2030. Monetary units are assigned to the direct economic impacts on different land use activities and discounted to their net present value. Successively, the result is compared to a statistical analysis using aggregated national data. In turn, the indirect economic effects are accounted for in the interpretation of the economic results. A qualitative analysis of the non-market relations, such as environmental impacts and other social issues, is made using elements from multicriteria analysis. The main areas taken into account are merits derived from indigenous knowledge and culture, and the potential benefits in relation to the protection of biodiversity. Further, the cost-benefit per ton carbon sequestrated in the mitigation scenarios mentioned, is compared to other climate change mitigation options, such as energy efficiency schemes. The methodology presented is finally discussed in the light of methodologies used analysing biodiversity protection projects and other environmental issues.

Steffen Rønsholdt Nielsen

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REGIONAL ASPECTS OF CLIMATE CHANGE MITIGATION

Internationally coordinated action by developing countries could help to mitigate global climate change in ways that are environmentally, economically and socially beneficial. As part of the UNEP/GEF project on 'The Economics of Greenhouse Gas Limitations', a study of the prospects for such regional action is well underway.

International regions have received relatively little attention in the study of climate change mitigation, for most of the work to date has concentrated upon the national level. Recognition, however, that extremely attractive possibilities may also exist at the regional level has prompted this investigation to move into the international level.

Some mitigation options depend upon cooperation between two or more neighbouring countries – for example, sharing offshore gas resources or integrating transportation infrastructure. Other options, moreover, are possible only by exploiting the economies of scale that emerge at the regional level – for example, developing either a large hydropower facility or a market for energy efficiency devices. Thus, it seems evident that regional action could, at least in theory, present mitigation options which are both cost-efficient and development-promoting.

The study aims to advance our understanding about the issue in two ways. First, it will begin to develop a broad methodological framework for assessing regional climate change options (like those suggested in the paragraph above). A variety of criteria will be developed to assess these options: climate-related (that is, savings in terms of greenhouse gas emissions that are abated and/or absorbed), economic (that is, the cost of such proposals), developmental (that is, how the actions would contribute to the region's own development goals, measured on a variety of social, economic and environmental yardsticks) and institutional (that is, what barriers to implementation might arise?).

During 1996, progress on the development of this methodology was realised. For one, the concept of a 'regional baseline' was investigated. Given that some regional options would clearly impact already-developed national options (an international market for a particular renewable energy technology, for example, would make any calculation of the same in the strictly national context obsolete), the impact of regional options upon national strategies obviously warrants attention. Moreover, in light of the unique institutional and political challenges that arise when we take the analysis to the international level, particular investigations were also undertaken in this area. Research revealed that the importance accorded, for example, sovereignty, distributional effects and power could make regional options that much more difficult to implement.

The study will also apply the methodology to two specific international regions in the developing world: the Southern African Development Community and the Andean Pact. In the African case, it appears that the integration of electricity supply systems at the regional level could serve to reduce carbon dioxide emissions significantly: the vast hydropower potential in the northern part of the region (for example, along the Zambezi River) could meet the large demand for electricity in the southern part of the region (particularly South Africa and Zimbabwe), which might otherwise be satisfied by these countries' large coal reserves. In the South American case, meanwhile, the development of a regional market for natural gas could also serve to mitigate climate change, again by displacing more carbon-intensive ways of generating electricity.

Findings from this project, which will begin to emerge in late 1997, will contribute directly to policy discussions — not only in the two sets of countries under specific examination, but in other regional groupings as well, as their representatives consider their own regional mitigation options. Although regional options are not expected to deliver all of the answers, they could well offer new opportunities for climate-change mitigation. Accordingly, it would seem that study into regional options can only increase the chances of creating a portfolio of climate mitigation options that is efficient and fair.

Ian H. Rowlands

RISK ASSESSMENT OF INDUSTRIAL FIRES

TOXFIRE project

The project Guidelines for Management of Fires in Chemical Warehouses (TOXFIRE) has been finalised in 1996. The main outcome for 1996 have been the results of the chemical fire experiments carried out in various scales and the development of two sets of guidelines in relation to chemical fires in chemical warehouses. Fire simulation is an important element within the field of fire prevention and fire protection. Fire experiments carried out at various scale can provide information on the burning characteristics of chemical substances and the composition of the fire effluents. Such findings are essential for the fire brigades as well as the safety engineers, as it will provide a basis for the development of realistic fire scenarios and improve the possibilities for fire prevention and control of fires.

The TOXFIRE project has been carried out by an international consortium during a three-year period (1993-1996) with Risø National Laboratory as co-ordinator.

Microscale experiments

Risø is simulating chemical fires in a microscale. A fire simulation needs only one to three grams of a substance and is performed in the laboratory. Therefore, many different substances, even toxic ones, can be combusted without the danger of any adverse effect on people and the environment. The combustion experiments are carried out in a tubular furnace according to the DIN 53436. The setup enables the performance of experiments under a variety of different fire conditions with respect to temperature and oxygen/fuel ratio. The combustion products are analysed on-line by means of Fourier Transform Infrared Spectroscopy or off-line by GC/MS methods. Using these methods the combustion compounds for many different substances e.g. pesticides, polymers and others have been quantified during the named project.

In 1996, all the experiments were finished and the major task for this year was to compare the experimental results from the different scale tests with each other. The applied scales are micro-, bench-, medium -, large- and huge scale, and are performed in a DIN 53436 tube furnace, ISO 5660 Cone Calorimeter, 1/3 room size setup, an ISO 9705 room and an extra large size room setup, respectively. Furthermore, five common substances have been chosen for the scaling analysis: polypropylene; nylon 6,6; tetramethylthiuram monosulphide, 4-chlor-3-nitrobenzene and chlorobenzene.

During the TOXFIRE project a number of improvements in the experimental setups have also been made to be able to compare the scaling results. This was mainly with respect to better control of the burning conditions e.g. the fuel/oxygen ratio, which is a very important measure in fires. Also the chemical analysis was improved by adding FTIR and GC/MS instrumentation to all experimental setups.

On the basis of the experiments with the five chosen substances a comparison of the scaling effects was made possible. The comparison was

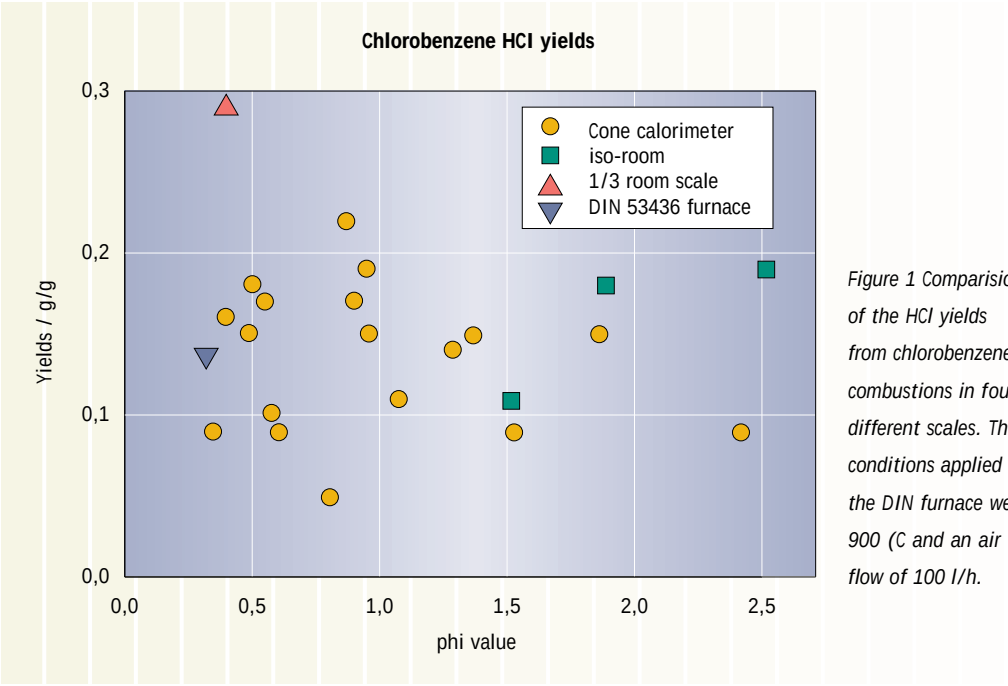


Figure 1 Comparision of the HCl yields from chlorobenzene combustions in four different scales. The conditions applied in the DIN furnace were 900 (C and an air flow of 100 l/h.

done by correlating the yields of CO_2, CO and HCl and soot particles with the temperature of the upper layer gas temperature and mainly with the fuel/oxygen ratios (phi-values) during the burning. In figure 1 an example for this is shown. It is seen that the yields for HCl are in reasonable agreement for all scales. Summarising all the results, they show that the results for all scales are in reasonable agreement with respect to the identification of the possible combustion products and of their relative importance. This means that Risø's microscale work is relevant and applicable to simulate chemical fires under different fire conditions.

Fire risk assessment of chemical waste

The experience gained from the TOXFIRE project has been applied in a fire risk assessment study of the chemical waste at a Danish chemical company. The analysis was carried out by request from the Danish Environmental Protection Agency and comprised the following issues: Characterisation of waste types and collection of samples, hazard identification and assessment of fire cases, fire simulation: combustion experiments, assessment of the composition of the fire plumes from real fires and consequence assessment: incident heat flux, plume rise and dispersion calculations.

The study comprised four types of chemical waste which were combusted under three different fire conditions in the DIN furnace: a) Developed fire at full ventilation (900°C, 100 l/h air), b) Developed fire at reduced ventilation (900°C, 25 l/h air mixed with 75 l/h nitrogen) and c) Non-flaming fire at reduced ventilation (500°C, 25 l/h air mixed with 75 l/h nitrogen). The fire effluents were analysed by use of FTIR and GC/MS. The analysis concluded that for large fires with large releases of heat plume rise will occur, and for small fires with low combustion efficiencies lift-off will not occur and the plume will stay at the ground resulting in high concentrations of fire products close to the source. The study illustrates the applicability of the developed experimental facility.

Further development

The TOXFIRE project has been concluded by the end of 1996. The project results show the areas where it is important to refine the present knowledge on risk assessment of chemical fires. The areas are, e.g. a better understanding of the generation of poisonous nitrogendioxide and hydrogencyanide in a hazardous fire, the prediction of precursors to dioxin formation and the improvement of CFD modelling (computer fluid dynamically) on fires with regard to fire chemistry.

Publications in 1996: 78, 100, 120

Frank Markert & Birgitte Rasmussen

Knowledge from accidents must be transferred systematically to design and emergency management: Fire aboard a train in Channel Tunnel November 18. 1996. (©Nordfoto)

Both risk analysts and emergency managers deal with the control of danger at the point where control is most difficult. They approach the problem on different professional backgrounds however, and there is much to be gained from exchanging experience and knowledge. Also, in the public planning of land use one needs accident knowledge to support decisions on plant layout, safety zones and other restrictions.

MEMbrain is an EUREKA project running 1993-1998, the aim of which is to define and implement a standard European software and hardware platform for Major Emergency Management (MEM). In 1996 work was completed on:

- systematically extracting and presenting accident knowledge from a large selection (totally 24 cases) of accidents, representing the main accident types
- devise a formulation of the general accident knowledge collected, which can function in a scenario-generator or other type of accident data bank for training use.

The LUPACS project under EU's Environment & Climate program started1996.

MEMbrain

In the training of emergency managers accident processes like fire, radiation and structural collapse are referred to along with event sequences, which in combination create the space for emergency operations. An accident scenario can be copied from an actual accident case, it can be a reflection of reference scenarios in the contingency plans or it can be a postulated scenario made specifically for training of a critical emergency action.

Knowledge extracted from accidents should be representative, but it must also be structured in a pattern suitable for training purposes. Ideally, the representation should cover both the accident archetypes and the elements of system behaviour that are additional prerequisites for interpreting and controlling accident situations. To be representative, such knowledge has to be both true to the risk objects and significant to the trained subjects. The structuring of accident knowledge for training can be worked out with a view to both training psychology, computer technology and emergency training schemes. Compared to the usual reference scenarios, the MEMbrain scheme for accident information is more comprehensive and flexible, pointing towards future scenario generators, which are able to produce "accidents" in an interactive mode during training sessions.

The main steps in this project have been:

- defining a set of accident types classified in domains
- developing an accident model and a model for emergency measures.
- developing an overall frame for describing domains
- extracting accident knowledge from selected cases

The investigation featured ten specific domains: process plant, storage, nuclear power plant, energy distribution, marine transport of goods, marine transport of people, aviation, transport by road, transport by rail and natural disasters. Totally 24 accident cases were consulted and information was extracted for filling into the schematic representations with two to four cases pr. specific domain. The material illustrates some characteristic differences between accident domains, but the sample is by no means conclusive about such differences.

The storage of large amounts of flammable or chemically active substances lays the groundwork for potential disasters, especially because long-range accident consequences may threaten larger communities and at the same time delay emergency operations and evacuation. For storage of one or a few different substances like the typical NH3 - or LPG-storage, the real emergency challenge is with the rapid development of long range consequences from an accident. For industrial plants and for the transport of dangerous substances, emergency operations may be delayed and made difficult because of the need for identifying involved and

developed substances and choosing adequate measures. For the domains airplane, ship/ferry and natural disaster it is a depressing fact, that hundreds of human lives are at stake, and complete rescue in such disasters may be physically impossible.

Land use planning

A general interest in regional planning and attempts at controlling industrial risks are societal trends that both point towards land use planning where industrial activities are involved. Under the EU research program Environment & Climate the LUPACS project started 1996 with participants from France, Greece, JRC Ispra, Sweden and Denmark. Among the participants are representatives from the planning authorities in Sweden and Denmark. Land Use Planning And Chemical Sites deals specifically with the decision task of planners in local administrations, who are faced on one side with industry's applications for making changes and building new plants, and on the other with the range of conditions and impacts to review and evaluate in order to fullfil Seveso Directive and other relevant legislation. The aim of LUPACS is to develop a method to support the local planners in establishing a sound basis for their decision making on such issues as choice of safety distance, site selection and formulating restrictions on operation.

Publication in 1996: 43

Birgitte Rasmussen and Carsten D.Grønberg

Functional Analysis Used in the Design Phase of a Mini-Submarine

The inspection of submarine pipelines is a necessary part of the exploitation of offshore oil- and gas fields. Also submarine electrical cables need periodic inspection. The inspections are performed by divers or by means of remotely operated vehicles and are rather expensive. Using an autonomous vehicle, i.e. an unmanned mini-submarine which can perform an inspection without being in constant communication with a surface vessel, offers the potential for large savings in the long term. Therefore, a number of such vehicles are under development. One of these is MARTIN which is being built by the Danish company Maridan. The control for the vehicle is being developed in a research project, PIPESCAN, with participation from the Technical University of Denmark (TUD) and Risø. Risø's part of the project involves a functional analysis of the tasks to be performed by the control system. The analysis, carried out in 1996, serves as an aid in the design of the control system which has to function reliably in many different operational situations. Furthermore, the analysis forms the basis for an automatic diagnostic function which must be able to diagnose failure situations arising from internal failures in the submarine as well as external causes, such as obstacles in the path of the vehicle.

The vehicle

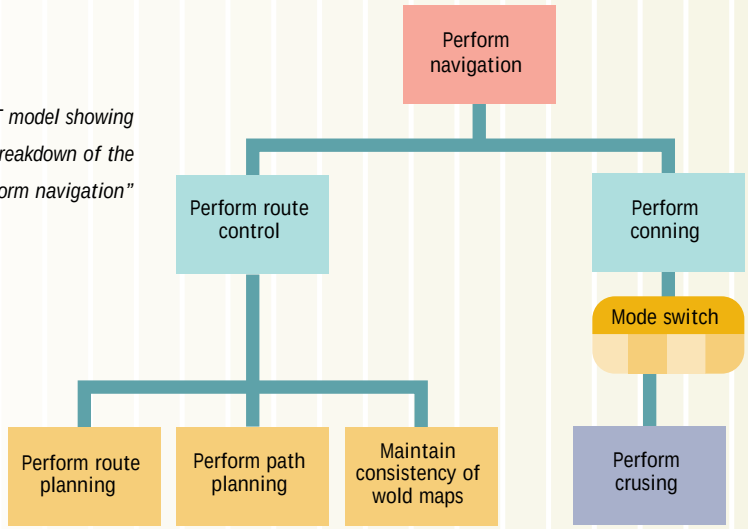
The MARTIN vehicle has a flatfish-shaped hull with fins, rudders and elevator. It has two main thrusters aft, three vertical and one horizontal thruster, giving it good manoeuvrability, even at low speed. The hull is open, and all electronic equipment is placed in watertight compartments. Propulsion energy comes from lead-acid batteries, giving the vehicle a range capacity of 80 kilometres. The on-board control system comprises four PCs for high-level control and 20 microcontroller boards for the low-level hardware control. A central part of the navigational equipment is the Differential GPS (DGPS) system.

Diagnosis system

The mission management system executes the planned survey, monitors the vehicle, communicates with the human operator and performs emergency actions as necessary. An important part of this software will be the diagnostic system. Local diagnosis will be included in all modules of the control system, checking the performance of each module itself and the other modules or hardware controlled by that module. In addition, a special module will be designed for a higher-level diagnosis. This module will be based on the comparison of the actual behaviour of the vehicle with that calculated by a model on the basis of actual thruster and rudder movements. Discrepancies will indicate a wrong vehicle condition or an error in the data acquisition.

Modelling of the functions to be performed

For the functional modelling of MARTIN the so-called Goal Tree - Success Tree (GTST) method was chosen. GTST features a hierarchical breakdown of



Excerpt from the GTST model showing the first few steps in breakdown of the function "Perform navigation"

goals into subgoals and subgoals into functions. Finally, it connects functions to components and software, which establish the lowest levels of the functional hierarchy.

A representative scenario was modelled in which the task is the performance of a video inspection of an oil pipeline in the Great Belt. The inspection result is to be a video recording of the pipeline. The scenario has the following main points:

- Launch of the vehicle
- Precise measurement of position
- Diving and cruising to the starting point for the survey
- Finding the pipeline
- Cruising along the pipeline and making video recording
- Cruising back to the mother vessel Docking

In the GTST model the main goal is the safe, correct and timely performance of the mission. This goal is subdivided into the subgoals: "Maintain safe operation" and "Perform mission correctly on time". A further subdivision of the latter identifies a number of functions which must be available in order for this subgoal to be fulfilled. Examples of these functions are: "Perform mission control" and "Perform navigation". The expansion of the latter is sketched in the figure. There are two main branches: the determination of the route to follow and the conning, i.e. the actual manoeuvring of the vehicle. The conning can occur in several modes, one of which is called cruising. A further breakdown of that mode eventually will identify components and software, such as rudders, thrusters and autopilot, necessary to perform the functions further up the tree.

Applications for the GTST model

When all the relevant branches of the functional model have been decomposed until the software- and component level the model is complete as far as its role in the design of control software is concerned, because at that stage the software modules necessary have been identified and the writing of the software can be performed.

Taking the GTST model further by making a failure analysis of the items in the software- and component level will provide the basis for the automatic high-level diagnosis system. This system will be able to identify which functions cannot be performed when one or more components have failed, and conversely it will point to potential causes when it is detected that a given function cannot be performed. The system will be programmed by means of available expert system tools. Within the frame of the present project, which runs through 1998, part of the GTST model will be converted in order to demonstrate the principle. Testing will be carried out by means of simulations and on the actual submarine in the laboratory and at sea.

Kurt Lauridsen, Palle Christensen, Henrik Østergaard Madsen

SAFETY AND RELIABILITY OF WIND TURBINES

Large wind turbines with 0.5 to 1 MW electrical power ratings have become standard products within the last few years. Such turbines are rather expensive, and the rotating parts are so large and heavy that they posses a hazardous amount of kinetic and potential energy if "released" under high wind conditions or in other accidental events. In order to protect the investments and the people around the turbines, there has been an increasing interest in the reliability and safety of these structures. Probabilistic methods appear to be applicable also in this field for predicting failures and their probabilities. This fact and the interest mentioned has given rise to research programmes both nationally and in the European Union, where funding has been provided. On the national level funds have come from the Danish Energy Research Programme (EFP) and at the European level from the EU programmes Joule II and III.

Stopping the rotating blades may take place during normal shutdown or when braking during an emergency. The normal shut down procedure will be to turn the propeller blade and rotate the turbine away from the wind direction with the yawing system. The electrical grid may offer some braking force as well. These are slow procedures, however. Emergency braking requires instant action. For the smaller wind turbines traditionally two independent, redundant safety systems for emergency braking have been required. They are normally implemented autonomously, and kept independent of the general control system as a mechanical brake, where all the braking energy is converted to heat, and wing tip brakes which sharply reduce the rotor speed when released. For large turbines this requirement could be quite expensive and also technically difficult to fulfill as the mechanical brake would then have to convert and dissipate the full rated power of the turbine or even more in a catastrophic situation. A mechanical brake for a 1-MW machine is therefore not a simple device. Furthermore, the sudden braking action may have a detrimental effect on the rotor blades. For these reasons the possibility of designing the same reliability into a single emergency brake as was found in the older redundant sytems is under consideration.

Three projects have been carried out jointly with the Test Station for Windmills at Risø National Laboratory. In 1996 the first and the last project mentioned were completed, while the second was launched.

Evaluation of Wind Turbine Safety

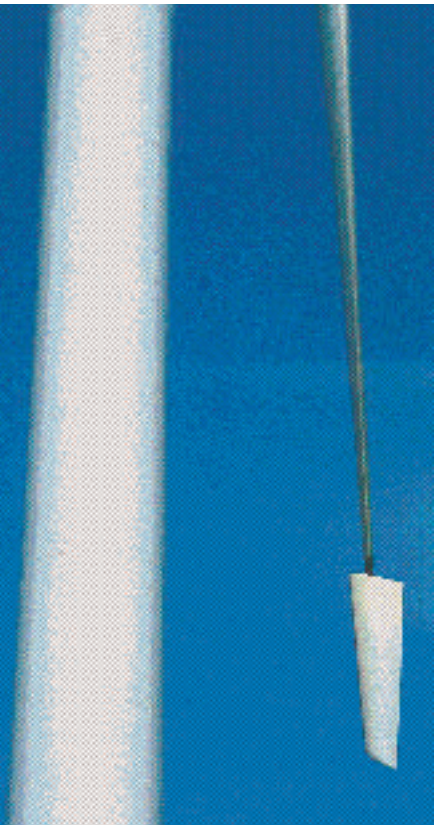
Risø's contribution to the Joule II European Wind Turbine Standards Subproject 3 programme was a project carried out within a working group consisting of ECN, Petten, Germanischer Lloyd, Hamburg and Risø. The main task was the development of failure models for wind turbines, especially for the top event of the safety system. Within Joule II only qualitative considerations were included, which means that only causes of top events and fault trees for the latter were considered.

Methods for constructing failure models were chosen from the selection of methods known from other fields, e.g. the nuclear and the aviation fields. It has been recommended that the analysis be initiated with a careful Failure Mode and Effects and Consequences (FMECA) analysis followed by an Event Sequence Analysis or a Cause Consequence Analysis of potential hazardous events identified in the FMECA analysis combined with an identification of the so-called Initiating Events. These steps will lead to the identification of the top events of interest, and fault trees can be constructed. In fact, normally only one top event is analysed, i.e. "Overspeed of the rotor", as this is by far the most frequent event leading to total damage of the rotor and tower.

Quantification of Failure Probabilities

The work within Joule III, European Wind Turbine Standards II, Subproject 2 is a continuation of the project mentioned above with the same working party. In this project the models created earlier are being extended to become quantitative, i.e. probabilities may be predicted for the top events identified earlier.

In order to place electricity production with wind turbines within the scope of public acceptance of risks imposed on the population by industrial activities, investigations are being made into the field of public risk acceptance levels for imposed risks. There are quite different traditions in the European countries for the attitudes of authorities towards risk



Deployed wing tip brake

acceptance. Two main lines of thought are dominant. In some countries it is believed that construction in accordance with deterministic rules and standards will give an acceptable risk level, while others believe that the maximum permissible risk level imposed on the public should be demonstrated by means of a probabilistic risk analysis. The projects aim at finding a proper European balance between the two lines of thought.

Safety Systems for Windmills

This EFP-project has been carried out simultaneously with the two other projects in close collaboration with two fully participating Danish wind turbine manufacturers,
BONUS Energy A/S and NORDTANK ENERGY GROUP A/S and the company ELSAMPROJEKT A/S.
Within a Windows-based program a data base for the registering of faults reported in company service reports has been combined with failure models for the large turbines of the two companies. This facilitates the use of fresh fault data in the models as a more realistic complement to the generic data taken from e.g. handbooks, which is the normal source of failure data when no recorded failure data are available from the actual system. At the higher level the failure models follow the standards described under the Joule sections above. At the model execution level computer codes such as FAUNET developed at Risø for the fault tree anaysis are used.
A fairly successful user interface to the data base and the programs was developed, too.

Conclusion

Methods for predicting the reliability of large wind turbines have been defined. This has given manufacturers, classification companies, and authorities a qantitative means for comparing the reliability and safety of different designs of wind turbines and their safety systems. The traditional principle of protection with two redundant and independent safety systems is still preferred, but the tools for comparing designs with philosophies other than the traditional are now available. The reason for the conservatism may be found in the scarceness of actual fault data for contemporary wind turbine components. When more data are available the predictions will contain increasing evidence, but although uncertainty always remains they will be handled more realistically.

Publications in 1996: 63, 64, 65

Palle Christensen

IDENTIFICATION OF HIDDEN FAILURES IN PROCESS CONTROL SYSTEMS

The project has been carried out as a part of the requirements for obtaining the Ph. D. degree at the Technical University of Denmark. The objective of the project has been to develop and use a function-oriented failure analysis method for the identification and representation of hidden failures in process control systems.

Qualitative failure analysis of complex industrial plants is usually carried out by examining the plant for the causes and consequences of failures in its physical components. Several methods using this approach have been developed and successfully utilised on various types of industrial plants. Examples of such methods are Hazard and Operability (HazOp) Analysis, Failure Modes and Effect Analysis (FMEA), Fault Tree Analysis (FTA), Event Tree Analysis (ETA) and Cause-Consequence Analysis (CCA).

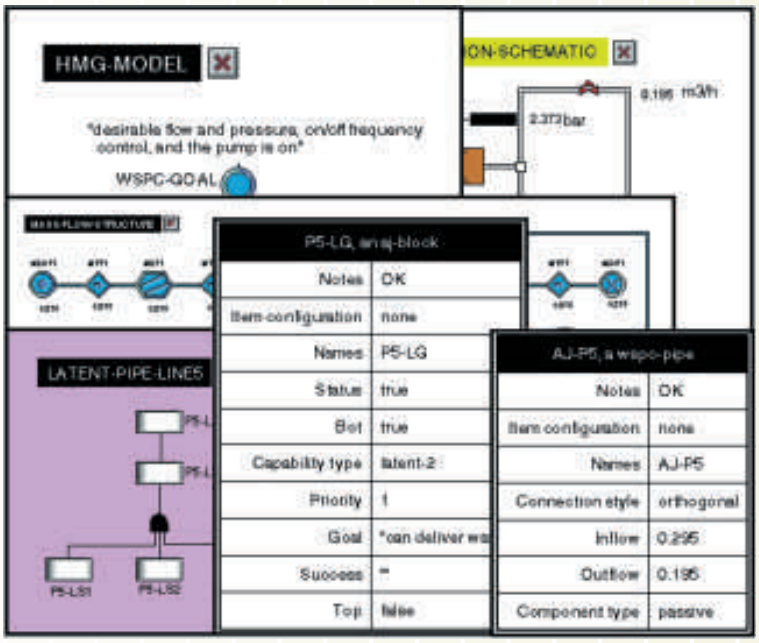
In spite of this, the methods have not been able to offer a fully satisfactory solution to the problems concerning hidden failures that are particularly related to control systems in complex industrial plants. The dynamic nature and disorder-suppressing mechanisms in control systems often enable such systems to compensate for some plant failures that do not prevent the overall goals of the plant from being achieved within a certain time interval. Such failures can therefore cause the control system to become overloaded and eventually unstable if they are not recognised at an early stage of progress.

Considering a technical system to consist of a number of components and defining the failure to be an unintended capability of a component to affect the realisation of one or more functions, the objective of a failure analysis method could then be to clarify what goal sets the system must achieve, what functions contribute to the achievement of each goal set, and what component capabilities can realise each function. Classical failure analysis methods focus on a particular goal set defined for the system, and thus on deviations from particular functions needed to attain the goal set. That is to say, only functions of a component immediately responsible for achieving those goals are considered, and if these functions are all realised, it is concluded that the system is free from failure. This also means that only those failures that have already affected the goal set will be identified. What is important about hidden failures is that the plant exposed to them is capable of achieving all its goals within a given time interval. This is due to the ability of the system components to realise other functions necessary for achieving other goal sets. As a consequence of ignoring one or more of these functions and hence component capabilities, some possible sources of failure may be overseen.

The life cycle of a technical system involves four different factors: design, make, use and maintenance. There is a purpose behind each of these factors, and this purpose can be expressed in terms of the goals and functions of the system that are fulfilled and realised due to the capabilities of the system components. The goals, functions and capabilities of a technical system are some of its basic aspects.

The difference between the designer's, maker's and user's intention, along with the fact that a technical system can have several designers, makers and users, and can be very complex, indicate that the system must have capabilities to realise activities which in connection with certain groups of goals can be conceived of as functions. However, the same activities can be considered as unintended or even unwanted with regard to other groups of goals. Unwanted activities in technical systems are also called failures.

The maintenance task consists of planning and execution. The intention of the individuals performing the execution is to follow the instructions given by the plan. The intention of the planner is to ensure that the system continues its life cycle, and this is done by monitoring the various ways that the system is "used" and by taking necessary actions if the user-defined goals in each way either contradicts the designer's and maker's, or exposes a contradiction between these two groups of goals. Failure analysis is the task of identifying those contradictions, and the proper way to perform this task is through knowledge of the goals defined by the designer, maker and user, and this can be obtained through knowledge of the functions of the system according to each of those groups of goals and not only one of them. A systematic identification of these functions leads to a systematic identification of system capabilities, some of which can be the sources of failures in relation with some of the goals.



The prototype of a knowledge-based system: A hidden failure that has been identified by using the HMG method.

The work carried out has resulted in a function-oriented analysis method for identifying and representing hidden failures through the identification and representation of knowledge about the basic aspects of technical systems. As long as the knowledge identification is concerned, the method utilises a developed terminology to help extracting knowledge about technical systems, which includes knowledge about their goals, functions, capabilities and physical structures. The features of two function-oriented modelling approaches, the Multilevel Flow Modelling (MFM) and the Goal Tree-Success Tree (GTST), have been used in the knowledge representation part of the method. In this part, the explicit representation of the interconnections among goals and functions by the MFM model, and the representation of knowledge at the component level by the GTST model are used to develop a tailored combination of these models. With few modification, the ideas behind these models are used explicitly to model the goals and functions, and the capabilities and physical structures of technical systems, respectively. The developed method is called the Hybrid MFM-GTST (HMG) method, although using the two approaches is related only to the representation part of the HMG method.

The architecture of a knowledge-based system, that utilises the resulting HMG model of technical systems to the task of diagnosis has also been suggested. The building blocks of the system comprise two groups of generic and application-specific knowledge bases, and a diagnosis knowledge base to accomplish the diagnosis by using the information received from the two groups of knowledge bases. An application-oriented prototype of the knowledge-based system is equally implemented using the object-oriented software environment G2. The figure shows a snapshot of the result of a single run of the prototype.

Publications in 1996: 54, 55, 56

Atoosa Jalashgar

A STUDY OF CAPTAINS' PERFORMANCE DURING SIMULATED VOYAGES

In 1996, the department has carried out a detailed analysis of the results of a navigation training course at the Danish Maritime Institute (DMI). The course was conducted in a full mission simulator at DMI for bridge officers employed by a European ship operator and the analysis is based on data from 53 captains and 90 voyages, each of which was either a relatively short departure scenario down an estuary (about one hour) or a relatively long arrival scenario up the estuary (about two and a half hours).

The data that went into the analysis include, besides information about the captains' age and their time in present position, the following:

Navigation instructor's scores: for each segment of a voyage, each captain would be assessed on four aspects of performance. These scores or "grades", which were given on a 9-point scale, express the instructor's assessment of a captain's performance in terms of: (A) the margin of safety with which the navigation of this segment was carried out - did the captain have a grounding or a near-miss or did he throughout this segment of the voyage keep safe distances? (B) the timing involved - e.g., was there any room left for contingencies, was speed appropriate in the circumstances? (C) his management of resources, both technical and human resources - e.g., did he distribute tasks and recruit assistance when needed? (D) his pattern of communication - e.g., did he take notice if crew members expressed uncertainty and did he ensure that they understood his intentions and perception of the situation.

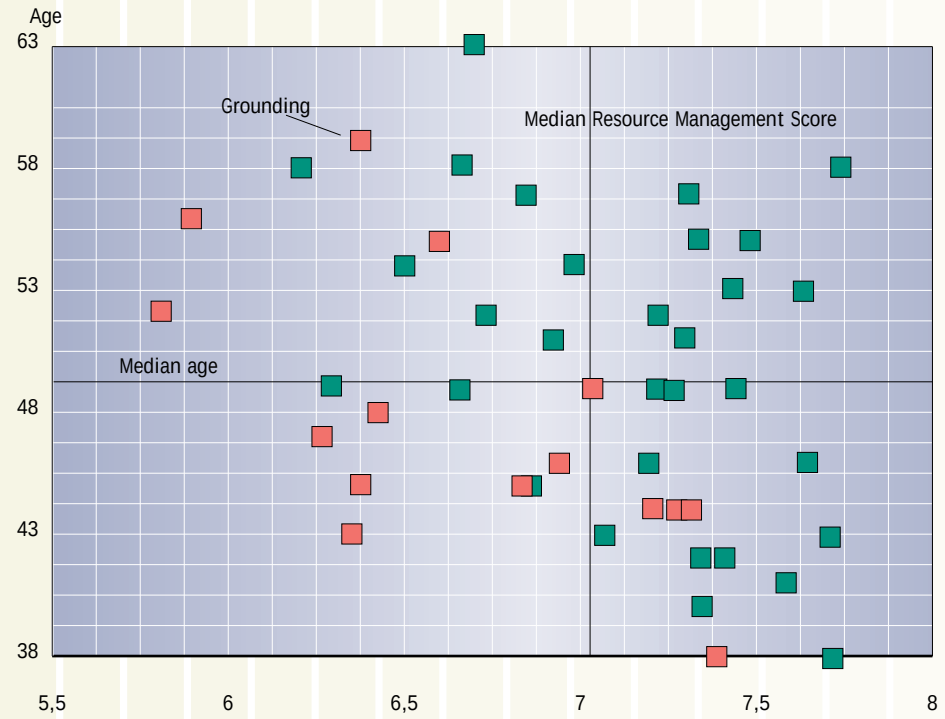
Classification of what was said on the bridge had been carried out by a psychologist into large linguistic groups: for each utterance the psychologist had recorded its originator, whether the utterance was a command, an observation, a question or a reply (or inchoate) and whether it concerned the past, future or current situation.

Finally, "objective" incidents, namely groundings or near-misses, were identified and verified against video recordings and track replay system.

Results:

- The four performance scores made by the navigation instructor - Timing, Safety, Resource Management and Communication - turned out to be significantly correlated: if a captain was rated at the higher (or lower) end of the scale on one of these, he would most likely be rated at the higher (or lower) end on the other three. Still, the correlation between Communication and each of the other three categories was, while impressive, still a bit weaker.

- It turned out that a captain's age was markedly correlated with incidents: older captains had a significantly lower risk of having had a grounding or near-miss during their simulated voyages. See also accompanying figure.



The figure illustrates the relationships between age, incidents and instructor scores. The example chosen here is "resource management" which is plotted against age. The age profile is depicted on the vertical axis and each captain's score on resource management is depicted on the horizontal axis. Red dots represent captains who had at least one incident and green dots those who had none.

A strong correlation was found between incidents (groundings and near-misses) and the navigation instructor's ratings on each of the three categories Timing, Safety and Resource Management (the TSR categories). But, there was no significant correlation between incidents and the scores captains received in Communication. Thus, if a captain has received a high score on any of the TSR categories, there is a high probability that none of his voyages contained a grounding or near-miss. On the other hand, the fact that a captain experienced a grounding or near-miss cannot be used to predict his score in the category Communication.

There was a significant correlation between Age and navigation instructor scores: older captains received a lower rating in the categories Safety, Resource Management and Communication, but not on Timing.

Finally, the categorisation of "what was said" on the bridge was demonstrated to have no correlations to navigator instructor scores nor to Age or incidents except for an interesting and statistically significant relation between incidents and the temporal aspects of speech. Thus, captains who had a relatively high percentage of their communication oriented towards future events had a significantly greater chance of not having incidents. The analysis, which was conducted in collaboration with DMI instructors, is part of the department's ongoing research into factors which influence safety and performance in areas such as maritime operations, aviation and process control. Results of the analysis will be used to shape future training courses and assessment of training effects.

Publication in 1996: 6

Henning Boje Andersen, Steen Weber

ENHANCED MARINE SAFETY

Captain on the bridge of the full mission simulator (DMI fotoarkiv/ Gitte Thorold)

Navigation in modern merchant marine transportation is faced with a line of factors giving rise to critical safety issues: vessels are build to carry bigger loads; speed is constantly increased; and coastal waters are characterised by a still growing traffic density and diversity. Yet, in spite of the consequential work complexity, safe navigation must be maintained at all times to avoid human loss and environmental hazards.

Marine safety projects

Technical innovations like double hull constructions, robust diesel engines, and advanced manoeuvring facilities have reduced 'mechanical failure' to be the caurse of only 20% of today's marine accidents. The remaining 80% are attributed to 'human error'. To this end, several research initiatives towards a better understanding of the human factors in navigation have been launched. As indicated by the title 'Safety of Shipping in Coastal Waters' the SAFECO project is concerned with navigation in and around harbour areas. Most marine accidents occur close to land. In 1996 the SAFECO project and a related PhD-project focused on understanding and modelling the activities and decision making undertaken by the crew. This has then provided input for a computer-based navigation simulation system and as a basis for setting up requirements for improved navigational support technology. A series of empirical studies of navigation in coastal waters were carried out at the full mission simulator facilities of Danish Maritime Institute. The simulator was running one of the world's largest container carriers and navigation was performed by a four person crew in the heavily trafficked and narrow channel leading up to Southamptton harbour. The crews' general performance and communication structures were carefully analysed by means of video recordings and track plot re-plays of each scenario.

Navigation

Basically the movements of a sea going vessel are determined by the interactions between controllable and uncontrollable physical forces. The manoeuvrability of the vessel is often heavily constrained by natural forces like wind and current. Consequently, to avoid risky navigation a manoeuvre plan is laid out prior to any significant course change. While executing the manoeuvre most of the navigational work is focused on continuous comparisons between the actual and the planned performance of the vessel.

Our findings indicated that the constantly increasing complexity of navigational work has been a prime factor in the breakdown of the traditionally very strong hierarchy on the bridge in favour of collaborative team-work. When sailing in coastal waters information relevant to the navigation clearly exceeds the capabilities of a single person. To master the Southampton scenario took the intensive cooperative efforts of the four persons.

The state of affairs in the overall navigational system (vessel and environment) is available for interpretation through the view and a multitude of instruments and artefacts. Our analysis illustrated that the flat structure of the bridge crew puts considerable emphasis on coordinating individual actions. The individuals have to mesh, allocate, relate, etc. their distributed activities to perform efficiently and effectively, i.e., they have to agree who is doing what, where and when. The general structure of task allocation is achieved through predefined individual roles and areas of responsibility. The prime guide for action is the combination between experience and currently available information, allowing the operators to form a picture of the state of affairs in the navigational system. Action is based on understanding the sta-

te of affairs. Hence, there is a need for information distribution among the various actors. For the operators to work closely together the individual interpretations of the system state need to be valid and to a large extent coherent and shared among the operators.

Towards increased support

Each of the four operators on the bridge have individual primary sources of information: helm; sea chart; radar; graphical GPS, as well as a large collection of instruments located in the main console. Establishing a shared understanding of the state of affairs is like putting together the pieces of a jigsaw puzzle; each of the operators possesses a central piece.

Despite the heavy use of technology on the bridge our experiments indicated that verbal distribution of all information relevant to the navigation plays a crucial role in the continuous process of making publicly known and putting together the pieces of information. Observations like the spotting of navigational marks, e.g. a buoy, are broadcasted immediately. Subsequently, the observation will be further concretised by means of the instruments on the bridge: If the radar operator spots a buoy he will turn to the radar to identify the specific buoy in the radar-image, point out the buoy in the sea chart, and pass on the information to the captain by pointing out the buoy on the graphical GPS. Thus, information is distributed not only verbally, but also by mapping information representations onto varying media.

Track plot showing part of the channel leading up to Southampton. The X'es are buoys. The track plots were an important source for the analysis.

An essential observation was that navigation is a highly cooperative work domain. The task to be handled exceeds the capabilities of a single person and the multiple individual perspectives of the cooperative work ensemble reduces the error potential. The information is distributed for mutually critical assessment. However, organising the work in the form of cooperative work functions has a number of unfavourable side-effects. The intense verbal information distribution and continuous transformation of representations are major contributors to the overall workload. Factors like high speed and dense traffic mean that the operators are bombarded with information when navigating in coastal waters. The studies indicate that the resulting information flow—at its extreme—will exceed human capacity. Consequently, priority will be given to non-cooperative work; information distribution and mutually critical assessment will be carried out only at a minimum, thereby increasing the error potential.

With the general objective of enhancing marine safety, the obviously problematic level of complexity involved in today's navigation is presently being analysed for possible solutions. New concepts are being developed for better support of traffic coordination are made through advanced 'Vessel Traffic Service' centres on land. And on the bridge, Integrated Bridge Information Systems, utilising the powers of contemporary computer technology to reduce information complexity through high level representation of navigational data are being investigated.

Publication in 1996: 19

Peter Carstensen and Morten Nielsen

TRAINING OF PRE-HOSPITAL PERFORMANCE IN EMERGENCY SITUATIONS; AN APPLICATION OF MEMBRAIN

During 1996 Risø has participated in a European project, MEMbrain, which copes with major emergency management. The project, which is partly funded by EUREKA, is an international one aimed at developing a computerised decision-support system for handling environmental and other major crises. MEMbrain is a total system, built up by modules tailored to each application. The system is designed for instant mobilisation, thus including durable sensor packages able to work under the roughest conditions. The basic concept of MEMbrain is to reduce human, environmental and economic losses, and ensure that decision makers in industry and authorities have the necessary foundation for making informed decisions in emergency situations. Besides being a decision support system, the system will include training facilities in order to allow the users to benefit from performing realistic training sessions by utilising the simulation capacity of the system.

In this project Risø is responsible for two modules: the communication module that guaranties efficient and safe communication among the various parts of the emergency managing organisation, and the training module that may be used for training decision makers of the emergency managing organisation as well as for testing the procedures used by this organisation. The information system MMS (Message Management System) is an e-mail system including specific features securing a timely and efficient communication among the organisational units involved in the emergency situations, and this module has been completed as a commercial product. The training module is based on the concepts developed inside the framework of Environment, the MUSTER project, which is a training concept including an illustrative prototype of a training system for training the co-ordinated performance of decision makers coping with emergency situations; i.e. co-operation among the various organisations involved: the fire brigade, the police, the paramedics, the utilities involved, etc.

The training system is meant to be a generic system usable for various domains and applications; during 1996 a specific application of the training system has been developed, which was dedicated to the training of pre-hospital efforts in emergency management, and the first version of a prototype has been completed. The training system fulfils the demands from the domain of hospital emergency planning centres and medical attendants concerning increased efficiency of rescuing efforts through enhanced first aid on site and improved overall co-ordination among involved organisations in coping with emergency situations.

The background of this action is that - as a relatively new approach - it is becoming normal practice at larger accidents to move the medical care from the casualty ward, being the first position at the hospital which receives the casualties, to the site of the emergency, in order to provide a faster - and thereby more efficient - support to the casualties.

Yet, this situation is still new to most of the medical attendants who have quite new working conditions and less equipment available as compared to their normal working situation at the hospital. This is a far different situation from workers in the other rescuing organisations, e.g. the fire brigade and police forces, to whom on site operation is the normal situation.

Therefore, there is a strong wish inside the medical domain to conceive and execute training sessions partly on its own in order to achieve a skilful performance in the new environments, i.e. to train enhanced first aid on site, and partly together with the complete emergency managing organisation in order to fit in adequately in a well-known and well tested structure of command, i.e. to train overview, disposition making, co-operation, communication, etc..

All parameters in the prototype concerning pre-planned actions may be specified in the input file as initial parameters. These are, for examples, the number, location and time of appearance of potential casualties, explosions expected to occur if the correct actions are not taken within a given time, and pre-planned changes of the weather situation. Dynamic actions, however, must be allowed to interrupt the execution, allowing the supervisor to interact with the scenario during the training session. This is due to the potential desire to facilitating or strengthening the session depending on the performance of the trainees, or to direct - if needed - the scenario along the lines dictated by the scope of the training session.

From the pre-hospital point of view the trainees are 1) the co-ordi-

nating doctor as the person in constant contact with the commander in charge of the operation as well as the medical world which includes the necessary expertise and knowledge of the capacity of available hospitals, 2) the triaging doctor, the person(s) sorting the casualties in relation to their timely needs of medical care, and 3) the treating doctor, the person(s) giving first aid on site to the casualties and preparing their transportation. Like the dynamic interaction of the supervisor, the trainees must be able interactively to influence the scenario via their actions in coping with the accidental situation in relation to their responsibilities.

In order to provide a flexible structure to the training system also from the point of view of software development, the system will be built modular with the modules being integrated on an integration platform, e.g. the patient simulation, the weather simulation, and the logging module will be developed as separate modules interacting with the module effectuating the training functionality, i.e. running the simulation that presents the training scenario to the trainees. A common time module will be needed for control of the various modules in order to have the complete system running as a single training session; and a graphical user interface, GUI, will present the evolution of the situation to the trainees and the training supervisor in accordance with their specific needs.

The time schedule concerning the pre-hospital training system is an illustrative prototype being prepared by Risø at the end of 1996, and a functional prototype being prepared by a Danish co-operating software house at the end of 1997. The latter, of which the validity has been assured through a very close co-operation with the hospital domain, will be distributed among a number of Danish hospitals for testing and approval; and this will be the basis on which the product will be matured and developed into a commercially available training module.

Publications in 1996: 3, 7, 8

Verner Andersen

Design Explorer: Semantic Information Retrieval in Communication Networks via Multimedia Techniques

The aim of the project is to develop models of the information needs and search behaviours of professional design teams as a basis for formulating the requirements to a multimedia prototype system that effectively supports information seeking and knowledge exploration in concurrent engineering in product development.

Groups of designers with different professional backgrounds, different domain expertise, and belonging to different departments cooperate across the organisation and meet in project groups to make design decisions about the product. Decisions cannot be made without detailed information about the product in the context of manufacturing, user application, marketing and distribution, maintenance and repair, disposal and recycling. Tools and methods for exploring current and expanding knowledge from such a wide variety of professional domains and information sources are needed. Work in 1996 focused on the analysis of information needs and the actual use and value of existing information sources using the framework for cognitive work analysis developed at Risø that address task activities, task strategies, domain expertise and co-operation among participants.
(figure 1).

One of several field studies conducted was the PVE project (Proportional Valve Electronics) at Danfoss A/S, which used a concurrent engineering approach in the design of an electronic controller to be inserted between the control levers used by the operators of fork - lift trucks, bulldozers, and similar heavy machinery, and the hydraulic cylinders operating the power tools. Such an electronic controller serves to establish a feedback loop that makes the control characteristics perceived by the operator independent of backlash, friction, load variations and other less stable characteristics of the hydraulic-mechanical system. Safety aspects are then central design issues. It is mandatory to ensure that faults within the electronic controller do not cause spurious movements of the power tools that can injure people or give rise to damage the work environment.

Through questionnaires and semi-structured interviews with designers with expertise from different professional domains, this and other projects offered an opportunity to study how project participants seek, create, store, provide and communicate information about safety and other issues to project partners, the form and media of this information required in formal and informal sources, personal communication, meetings, networks, reports, databases etc. The outcome of these field studies are a number of preliminary requirements and hypotheses for developing improved support systems.

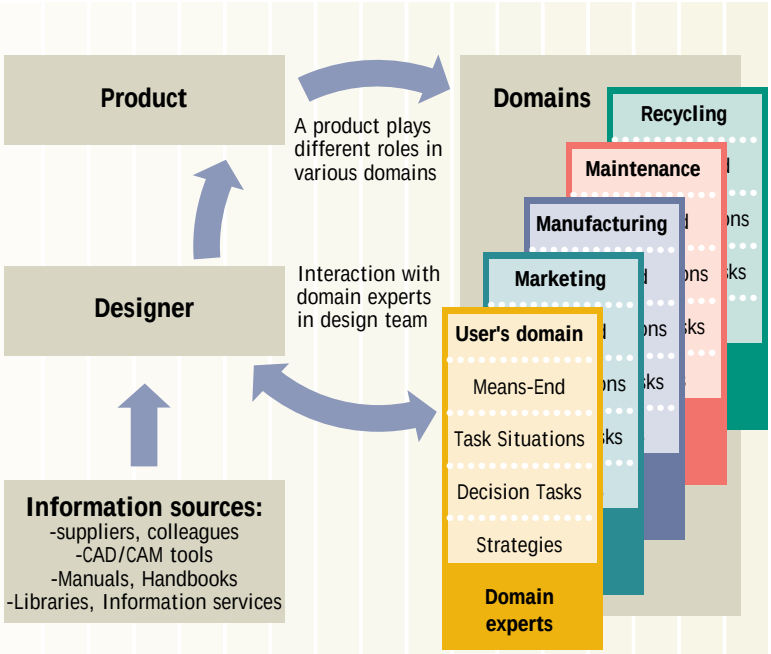


Figure 1 illustrates designers' exploration of the role of the product in different domains, task situations, decisions and strategies through interaction with domain experts and different information sources.

- Designers recognise relevant information when they see it, but it is difficult to ask questions as no familiar structure for asking is available. Asking information from designers from different domains with different knowledge levels, concepts and terminologies, increases this problem. An example of structures for knowledge organisation was found in a manual archive developed by the PVE design team as a personalised support system for their project group. Cross disciplinary databases with uniform semantic structures for organisation and retrieval of information are needed together with interfaces that translate concepts and terminology from different domains.

- Information overload is a major problem, in particular because the information is heterogeneous and the format is wrong. Scanning a large variety and amount of information is a frequently used approach for keeping updated. Attempts to create personal tools with good examples of similar products from other manufacturing companies were found. Access to databases with a large number of attributes that enable the searching for products similar to the design product is required. Support is also needed in searching for persons with expertise relevant for the products of the company and similar person expertise in other companies as well.

- Much information used for design decisions is created by designers themselves (in the form of surveys, videos, test data,laboratory experiments etc.), and they need models and integrated facilities that link recording, storage and retrieval of design information for later reuse in new projects.

- External communication of information plays an important role when specialists are located in another company or country. Fast communication means using the WWW and the Internet requires a basic software architecture for distributed work with local and external databases, intelligent agents and search engines available at the Internet.

An international network of researchers has been established to create a forum for exchange of theories, models and methods in humanistic research that can contribute to the understanding of the complexity of the semantic problems in product development in modern enterprises. A newsletter called “Design Explorer. Network for Engineering Design and Human Sciences” informs researchers and industry about the network meetings and the progress of the project. Participants in these activities are researchers from Denmark, England, Canada and USA, who represent a broad range of expertise from the human sciences, computer science and engineering.

As a network activity an international cross disciplinary workshop has been held in Copenhagen in June on the topics “ Empirical Studies of Information Needs and System Requirements for Product Development and Semiotic and Linguistic Approaches to System Design”.

Since complex communication network systems are characterised by a great diversity of heterogeneous information, future work will develop models to characterise the trade - off between the designers’ need for a uniform knowledge structure that match their tasks and the need for modelling each piece of knowledge in a format suitable for that entity. The analysis of knowledge representation and search strategies applied by a design team together with their co-operative patterns will be further addressed.

The project as well as the network is organised as a cross-disciplinary research effort, which takes place as a co-operative effort among Danfoss A/S and several universities in USA, Canada and England. Both are supported by the Danish Research Council for the Humanities.

Publications in 1996: 30, 93

Annelise Mark Pejtersen and Peter Carstensen

AN EXPERIMENTAL COORDINATION MECHANISM FOR SOFTWARE TESTING

In the complex work settings which are typical of modern industrial organizations, typically performing under requirements of high reliability, the necessary coordination of cooperative work may itself be a complex and demanding task. To cope with that, work organizations use a variety of formal organizational constructs such as prescribed standard operating procedures, checklists, forms, production schedules, time tables, routing schemes, classification schemes, etc.
In order to understand how software incarnations of such mechanisms can enhance the ability of cooperating ensembles to handle the complexity of coordinating their interdependent and yet distributed activities, the design and use of these devices — which have been named "coordination mechanisms" — have been investigated.

Based on in-depth studies of the use of coordinative devices in industrial settings, a conceptual framework has been developed which, in turn, has provided the basis for the construction of a software environment for designing and execution computational coordination mechanisms. The environment, which is named Ariadne, has been developed in collaboration with the computer science departments at the universities of Milano and Turino. The environment, which can be conceived of as an application-level extension to the operating system, offers a highly modular and distributed architecture which allows users to construct software coordination mechanisms which can be manipulated and combined in various ways according to the changing conditions of the work.

In parallel with the development of the Ariadne environment, an experimental prototype of a coordination mechanism for software testing has been developed. The purpose of the experiment was to obtain concrete experience with how to design and implement a computational coordination mechanism, especially by exploring some of the central ideas of the architecture of Ariadne (a stratified and distributed architecture and a high degree of modularity).

While Ariadne is an all-purpose development and run-time environment, the system — named Gordion — is a special-purpose software system dedicated to a particular domain, namely the coordination of cooperative software testing, or more precisely, the coordination of distributed registration, classification, diagnosis and verification of software faults. The development of the Gordion prototype thus builds on previous studies of software testing.
A crucial devise for the coordination of cooperative software testing is the so-called 'fault report form' which is used to ensure that faults are properly registered, that corrected faults were duly reported, and to make the allocation of responsibilities clear and visible to all members. As an artifact, the fault report form is a simple paper form. The agreed-to protocol for its use dictates that when a new fault is detected by anyone involved in testing the software, a new fault report is initiated and filled-in. The originator of the fault report also provides a preliminary description and diagnosis of the problem. Three designers acting as a so-called 'spec-team' then determine which module might be culpable and the designer who will be responsible for correcting the fault; they specify deadline when the fault should be corrected, and classify the fault according to its perceived severity. Each designer is then responsible for the correcting 'his' or 'her' faults and reporting back to the designer who is responsible for verifying and integrating the software modules.

Gordion which was finished in 1996 is a prototype of a software system which can support software testing in similar but more effective ways. In designing such a computational coordination mechanism, the crucial design issue was if it was feasible to build one monolithic application. The experiment showed that in order to support its distributed use, the system would have to be replicated on all work stations and the complexity of the system would increase exponentially with the number connections between the instantiations of the application. In short, the conclusion was that it is not feasible to build the system as a monolithic application which includes and handles all aspects of the protocol. Instead, a distributed architecture, in which different aspects of the protocol are handled by dedicated micro-applications which exchange messages, reduces the complexity of the protocol and the required facilities substantively. It was therefore decided to cut the proverbial Gordian knot and divide the system into a suite of separate software entities, each corresponding to a different organizatio-

nal role, instead of building one large application supporting all roles.
To users Gordion prototype offers the same degree of flexibility as paper-based forms but provides far better support in terms of routing, timely information, and overview of the state of affairs. For example, the system can be used in a routine-like fashion if changes to its behaviour are not deemed necessary. However, due to changing circumstances, users may need to modify the mechanism. The system should thus support users in modifying the mechanism, both at the time of its definition, i.e., in the form of permanent modifications, and during its operation, i.e., in the form of local control of execution. In short, computational coordination mechanisms must be malleable. An example of local control is a situation where a tester registers a fault, but the fault is simple to classify and fix, and the problem can be handed over directly to the relevant designer (see figure 1). In this case the tester can change the routing of the fault form by overriding the fault report mechanism by choosing a designer from the routing field.
Changes to the behaviour of the coordination mechanism may also be needed if the organization of the work has been changed. If this case, all future instantiations of the fault handling mechanism will need to be changed accordingly. In such a case, the change to the default routing of the mechanism can be made by choosing the 'save change' from the main

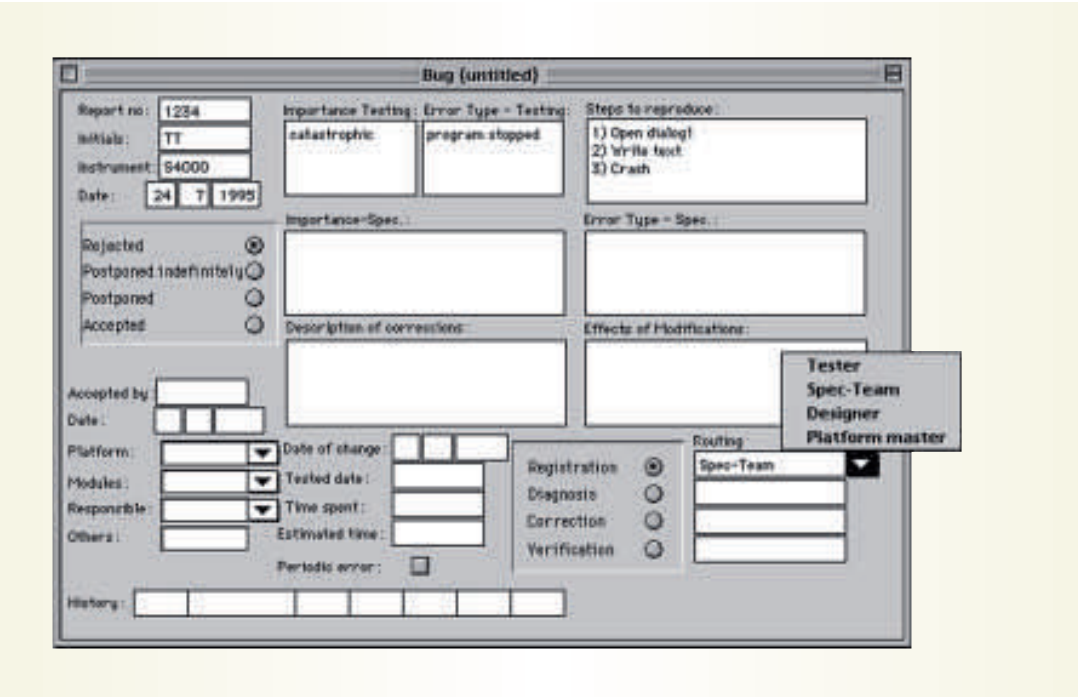


Figure 1. An example of malleability: The default routing of the standard protocol can be overruled.

menu; all those involved in the project will then receive a notification that the protocol has been changed. Altogether, the Gordion experiment has given valuable insights in the problems of computational coordination mechanisms and has pointed to some of the architectural solutions.

Publications in 1996: 20, 24, 25, 115, 117

Kjeld Schmidt

TEMPORAL ASPECTS IN COORDINATION OF DISTRIBUTED COOPERATIVE WORK

This PhD project is carried out in the field of Computer Supported Cooperative Work (CSCW) which includes several different research approaches. Some approaches focus on technical aspects of CSCW without a deep understanding of cooperative work while other approaches focus on understanding the cooperative work arrangements which must be computer supported.

At Risø CSCW research has covered both of these approaches and the core of this research has been to develop a framework for analysing and designing coordination mechanisms. A coordination mechanism reduces the complexity of the coordination to be conducted by stipulating the flow of the distributed work, and by mediating relevant information among the actors involved in the work. The framework is based on an understanding of cooperative work where the elemental categories of coordination work are described. Two such categories are task and personnel, so by means of a coordination mechanism it is possible to, e.g., coordinate which personnel should perform which tasks in a cooperative work arrangement. The different categories of coordination work have been formally modelled including descriptions of possible actions within each category and possible connections between categories. All of this has been described in a general notation for constructing computational coordination mechanisms and thereby a theory for CSCW.

Inside the framework temporal aspects of cooperative work have not yet been addressed in any detail. Therefore, the major goals for the project are: 1) to understand temporal aspects of cooperative work, 2) explore whether the existing elemental categories of coordination work and the possible actions performed within them are sufficient to handle temporal aspects of cooperative work, 3) formally model the findings within the general notation for computational coordination mechanisms, and finally 4) illustrate the findings through an illustrative prototype of a computational coordination mechanism.

Field study

During 1996 a detailed field study has been conducted in cooperation with Spedition Atlantic, a Danish forwarding agent firm, and Morten T. Sørensen, a haulage contractor. Its purpose was to find temporal aspects inherent to the distributed planning taking place in trucking. The planning is in nature distributed because it is performed as a cooperative task involving the forwarding agent, located in Hirtshals, and a truck driver located somewhere in Europe. Temporal aspects are present because the usual cargo transported by the trucks are either fish or fresh fruit, which can be characterised as perishables, and therefore just-in-time logistic planning of the deliveries are needed.

The field study focused on the communication between the forwarding agent and truck drivers, because this communication can document the coordination of the activities. Most of the communication is done by means of satellite communication equipment and almost 500 satellite messages were collected. Further the forwarding agents planning work was studied with the aim of achieving an insight in the temporal aspects inherent in the planning criteria they use.

Analysis and future work

In late 1996 an analysis of the field study findings was initiated to relate the observed coordination of temporal aspects of trucking, e.g., coordination of a delivery deadline between a driver and the forwarding agent, which in the framework of coordination mechanisms can be seen as a deadline of a task, namely the task of delivering. The purpose of the analysis is to find a set of primitives by means of which the temporal aspects of cooperative work can be described. At the present time one such possible primitive is duration, which describes how long time a given task/activity can/will last and whether it can therefore be used when coordinating, e.g., a deadline. Hopefully, several other primitives will be found during the continuing analysis.

The set of primitives can be described and modeled in the general notation for computational coordina-

tion mechanisms and therefore actions as, e.g., define duration of task, can be formally modeled.

Based on this theoretical work an illustrative prototype will be designed and developed. The prototype will illustrate a coordination mechanism including temporal aspects of the coordination in the trucking environment, and will be evaluated in the field by truck drivers and forwarding agents.

Steffen Herskind

CONFERENCES

In September 1996 Risø arranged the 3rd Seminar on European Research on Industrial Fires. The first two in the series were convened in Apeldoorn in the Netherlands in 1993 and in Cadarache in France in 1994.

The aim of the seminar which was financially supported by the EU/DG XII, was to bring together those currently working on EU-sponsored research projects relevant to industrial fires. Further, the intention was to supplement presentations of the status of their work with presentations of results of other relevant projects, nationally funded, and finally to include in the programme presentations of results of applications in industry and by regulators.

55 participants from almost all European countries were registered. The seminar programme addressed the following issues:

- experimental results
- fires including chemicals
- hydrocarbon fires
- mitigation
- guidelines/application
- dispersion
- toxic effects

For the first time a carefully planned series of experiments in varying scale was reported, showing that in many cases the small-scale facilities create sufficient information on the composition of the substances in the fire plume. This is very important, since lab-scale testing is much simpler and cheaper and eliminates large- scale tests which cause significant occupational and environmental hazards.

The seminar revealed some problem areas where further research is needed. One unsolved problem is the generation of nitrogen-containing compounds as a function of varying fire characteristics. Another problem is assessing the environmental impact of a fire from contaminated fire fighting water to rivers or the sea, and in particular addressing the dynamic aspects from initial fire through fully developed fire to extinction.

The seminar proceedings will be published early in 1997.

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Board of Danish Society for Simulator Training and Safety in Transport Industries (Sim Trans).
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Advisory committee on environmental and energy statistics (Statistics Denmark).
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Committee on energy statistics for transport (Min. of Environment and Energy).
Jørgen Fenhann.

Steering committee on maritime emissions in Danish waters (Danish Environmental Protection Agency).
Niels Kilde.

Steering committee on Emissions from Danish road traffic (Danish Environmental Protection Agency).
Niels Kilde.

Advisory Board (Danish Board of Technology).
Kirsten Halsnæs.

Steering Committee, Consensus conference on the "green consumption" concept (Danish Board of Technology). Copenhagen (DK) November 1996.
Kirsten Halsnæs.

Environmental Appeal Board (Min. of Environment and Energy).
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Committee for the future of libraries in the information society, UBIS udvalget (Ministry of Culture).
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International

IFIP Working Group 13.2 on User Centered Design.
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Editoral board, Journal of Loss Prevention in the Process Industries.
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Committee for European Standards on Nuclear Electronics (E.C).
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Executive committee: European Foundation for Coorporation in Energy Economics.
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Management and Policy Committee for UNEP Collaborating Centre on Energy and Environment.
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Halden Programme Group (OECD).
Kurt E. Petersen.

Editoral Board, Reliability Engineering & System Safety.
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Halden Ad Hoc Scientific Advisory Group on Human Error Analysis.
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Board of Management, Halden Reactor Project (OECD).
Hans Larsen.

Model Evaluation Group (E.U.).
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World Energy Council Programme Committee on Energy Issues of Developing Countries.
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IFIP Technical Committee TC.13 on Human-Computer Interaction.
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Papers Committee for Interact 97, IFIP TCB Sixth International Conference on Human-Computer Interaction.
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ENFLO Advisory Board (University of Surrey).
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IPCC Working Group III, Principal lead author on the Socio-Economics of Climate Change.
Kirsten Halsnæs.

IPCC Working Group II, Lead author on Methods for Assessment of Mitigation Options.
John M. Christensen.

IPCC Working Group III, Danish focal point on Emission scenarios and the Socio-Economics of Climate Change.
Kirsten Halsnæs.

UN/ECE task force on Emission Inventories. Panel on Maritime Emissions.
Niels Kilde.

Programme Committee for ESREL '96/PSAM-III, June 1996, Greece.
Kurt E. Petersen.

CEN-TC310/WG4, Ergonomics and Human Factors in Advanced Manufacturing Techniques.
Palle Christensen.

Cigré TF38.03.13. Sequentiel Probabilistic Methods.
Hans Ravn.

Board of Directors for TIEMS, The International Emergency Management Society.
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Programme Advisory Board, Fifth International Conference on Human Aspects of Advanced Manufacturing and Hybrid Automation, Maui, Hawaii, 7-10 August 1996.
Kjeld Schmidt.

Programme Committee, IAEE Conference on Transport, Energy and Environment, Elsinore (DK), 3-4 October 1996.
Hans Larsen (Chairman).

Organising committee for MIE'96 Congress, Copenhagen (DK) 18-22 August 1996.
Steen Weber.

Working group on Socio-economic Research on Fusion (E.U.).
Poul Erik Morthorst.

European Topic Centre on Air Emissions (EEA).
Niels Kilde.

International program committee. International conference on trasition to advanced market institutions and economics. Systems and operations research challenges. Transition '97. Warsaw (PL), 18-21 June 1997.
Hans Ravn.

Program committee. Nordic operations research conference. NOAS'97. Copenhagen (DK), 15-16 Aug. 1997.
Hans Ravn.

Associate editor. Energy Economics.
Poul Erik Grohnheit.

Council, International Association for Energy Economics (IAEE).
Hans Larsen.

Programme Committee. IPCC Workshop. Mitigation and Adaptation Costs and their Policy Implications, Risø (DK) June 16-18 1997.
Kirsten Halsnæs.

IPCC Writing Team for discussion paper Mitigation and Adaptation Cost Assessment - Concepts, Methods and Appropriate Use.
John M. Christensen, Kirsten Halsnæs, John M. Callaway.

Informal consultative forum for the exchange of experiences on climate change project development, implementation and follow-up - CC: FORUM (Climate Change Secretariat, Bonn).
John M. Christensen, Kirsten Halsnæs.

Programme Committee for TIEMS '97. The International Emergency Management Society Conference, Copenhagen (DK) June 10-13 1997.
Verner Andersen, Steen Weber.

Coordinating Editor of Computer Supported Cooperative Work. The Journal of Collaborative Computing (Kluwer Academic Publishers).
Kjeld Schmidt.

Scientific and Program Advisory Board for the First International Conference on Allocation of Functions, ALLFN '97, Galway, Ireland, October 1-3 1997.
Kjeld Schmidt.

Program Chair (Social/Behavioural Track) for the ACM Conference on Supporting Group Work (GROUP '97), Phoenix, Arizona, 16-19 November 1997.
Kjeld Schmidt.

Program Committee and Proceedings Chair for the Fifth European Conference on Computer Supported Cooperative Work, Lancaster, UK 7-11 September 1997.
Kjeld Schmidt.

Technical Programme Committee for ESREL '97, June 1997, Portugal.
Kurt E. Petersen.

MEG/Heavy Gas Dispersion Expert Group (E.U.).
Nijs J. Duijm.

Programme Committee for ACM SIGIR 97. 20th International Conference on Research and Development in Information Retrieval. Philadelphia, USA, July 27-31, 1997.
Annelise Mark Pejtersen.

Editorial Board, International Journal of Knowledge Organisation, USA.
Annelise Mark Pejtersen.

STAFF

Hans Larsen, M.Sc. (Elec. Eng.), Ph.D. The Technical University of Denmark 1972. From 1973 to 1976 at Dragon project at AEE Winfrith, U.K. Risø from 1976. Energy Technology Department 1976-80, working with systems reliability. Head of Energy Systems Group 1980-84. Head of Systems Analysis Department from 1985. Member of the Danish Academy of Technical Sciences 1993.

Charlotte Olsson, M.Econ. University of Copenhagen. Børsinformation Telecom 1990-92. IFX Scandinavia 1992-1994. Administrative officer at Risø from 1995.

Man/Machine Interaction

Leif Løvborg, M.Sc. (Elec.Eng.). Risø from 1962. Radioisotope techniques (1962-66), nuclear geophysics and mineral exploration (1967-86). Group Leader (Electronics Dept.) 1965-86. Human factors research from 1986. Acting head of Cognitive Systems Group 1990-92. Head of Cognitive Systems Group 1992-94. Head of the Man/Machine Interaction programme from January 1995. Main research interest: Simulation of safety-critical MMI systems.

Henning Boje Andersen, M.A. (Philos.), Senior Scientist. Copenhagen University and Oxford University (logic, philosophy of language) 1976-79. Medical Faculty, Copenhagen University and Roskilde University (philosophy of science) 1980-83. Risø from 1984, Systems Analysis Department from 1990. Main activities: Human-computer interaction, support of emergency management and multi-user training, evaluation of training transfer.

Verner Andersen, M.Sc. (Elec.Eng.), Ph.D., Senior Scientist. Risø from 1966. Nuclear physics (1966-76), plasma physics (1976-86). Leader of programme on plasma-physics technology 1983-86. Information technology from 1986. Systems Analysis Department from February 1990. President of the International Emergency Management Society (TIEMS) from 1996. Main activity: Project management, systems development.

Peter H. Carstensen, Ph.D. (Com. Sc.), Senior Scientist. Dansk Datamatik Center 1984-1988, Labour Unions' Centre for Informatics 1989-1991. Systems Analysis Department from February 1992. Main activities: Human-computer interaction, Evaluation of complex user interfaces, Computer Supported Cooperative Work, Methodologies for analysis of work in complex settings, System development methodologies.

Monica Divitini, M.Sc. (Com. Sc.) at the University of Milano in 1991. Milano University, Department of Computer Science 1992 - September 1995. Visiting researcher at Risø, Systems Analysis Department from October 1995 to January 1996. Main Activities: Computer Supported Cooperative Work, user modelling in cooperative environment, agent-based software.

Jesper Döpping, M.A. (Psychol.). Private consultant 1991-96, European Centre for Competence Analysis 1992-93, lecturer at the Institute of Psychology, Univ. of Copenhagen, 1996. Ph.D. work 1993-96 on knowledge and learning as distributed social practice. Risø from August to December 1996. Main activity: Evaluation of man/machine systems.

John Paulin Hansen, Ph.D. (Psychol.). Risø from 1988, Systems Analysis Department from February 1990 to January 1996. Major subject: Simulation, visual perception, recording of eye movements, evaluation of interfaces, MMI analysis and modelling.

Steffen Routh Herskind, M. Sc. (Com. Sc. with Math.) Roskilde Edb-school 1994 - 1995, Ph. D. student at Risø from June 1995. Subject: Efficiency in trucking. Applying CSCW to the transport sector to reduce the environmental adverse effect of truck driving.

Ann Britt Miberg, M.A. (Psychol.). Major subjects: Training, decision making, reactions of humans in critical situations. Ph.D. student at Risø from January 1993 to March 1996. Subject: Design of simulator training directed at train control operators' handling of emergencies/recoveries.

Finn R. Nielsen, M.Sc. (Appl. Math. & Phys.). Technical College of Copenhagen 1968-74. Risø from 1974. Systems Analysis Department from February 1990. Main activities: MMI simulation, implementation of software concepts.

Morten Nielsen, M.Sc. (Com. Sc.). Ph.D. student at Risø from January 1996. Ph.D. Subject: Computer supported cooperation and decision making in time and safety critical work domains.

Annelise Mark Pejtersen, M.A. (Sci. of Lit.), Senior Scientist. University of Copenhagen 1971-73, Associate Professor at the Royal School of Librarianship 1971-82, Acting Professor 1983-85. Visiting Senior Research Scientist at Georgia Institute of Technology 1982-83. Risø from 1986. On leave as manager of the Labour Unions' Centre for Informatics 1989-90. Systems Analysis Department from February 1990. Main activities: Cognitive work analysis, IT system design, Multimedia interfaces, Information retrieval and support systems for product development.

Kjeld Schmidt, M.Sc. (Sociol.), Senior Scientist. Roskilde University 1972-85, Dansk Datamatik Center 1985-88, Labour Unions' Centre for Informatics 1989-90. Systems Analysis Department from March 1990. Main activities: Theory and methodology for analysis of cooperative work in complex settings, Computer-Supported Cooperative Work, taxonomy of work domains.

Carsten Sørensen, M.Sc. (Com. Sc. with Math.). Ph.D., Senior Scientist. Department of Mathematics and Computer Science, Aalborg University 1989-1992. Systems Analysis Department from September 1992 to June 1996. Main activities: Computer Supported Cooperative Work, computer support for integration of design and process-planning in manufacturing, analysis of MMI systems.

Tuomo Tuikka, M.Sc. (Com.Sc.) University of Oulu, Finland 1992. Research Assistant 1993-1995, Post doc. at Risø from May 1995 to April 1996. Main Activities: Computer supported Cooperative Work, Software Processes, Testing, Prototypes of CSCW systems.

Steen Weber, M.Sc. (Elec.Eng.), Ph.D., Senior Scientist. Risø from 1972. Computer codes for nuclear fuel management (1974-75). Risk Analysis Group (Dept. of Energy Technology) 1975-84, Acting Group Leader 1982-83. Systems Analysis Department from February 1990. Main activities: Human computer interaction, Emergency management, Prototype development.

Simulation and Optimisation of Energy Systems

Hans Ravn, M.Sc. (Eng.), Ph.D. México 1978-1979 and 1987. Danish Energy Agency 1980-1983. Technical University of Denmark 1983-1995. Risø from April 1995. Head of research programme. Main research activities: Operations research, modelling, optimization, energy systems.

Peter Skjerk Christensen, M.Sc. (Elec.Eng.), Senior Scientist. Risø from 1958. Nuclear research and education (1958-69), reactor engineering and thermohydraulics including simulation models (1969-76), Systems Analysis Department from 1977. Stationed in Cape Verde Islands as energy advisor to the government (1991). Main activities: Energy systems modelling, renewable energy technologies, energy planning in Eastern Europe and Egypt.

Jørgen Fenhann, M.Sc. (Physics with mathematics and chemistry), Senior Scientist. Niels Bohr Institute 1977. Risø from 1978. Main activities: Development of energy planning models, new and renewable energy technologies, calculation of emissions from energy systems, and energy-environmental planning for Eastern European and developing countries.

Poul Erik Grohnheit, M.Econ., Senior Scientist. Danish Building Research Institute 1969-71, town planning consultant 1971-72 and 1979-80, economic planning and budgetting in local government 1973-79. Risø from 1980. Main activities: economics of electricity generating systems, electricity markets and energy environment economic modelling.

Christina Ingerslev, M.Sc. (Technological and Socio-Economic Planning), Ph.D. student at Risø from February 1993 until December 1996. Subject: Strategies for reducing the CO2 emission from the manufacturing industry, in particular dairies and papermills.

Henrik Klinge Jacobsen, M.Econ. Alm. Brand 1989-1991. Greenland Home Rule 1992-1993. Risø from December 1993. Ph.D. student at Risø from July 1996. Main activities: Macro-economic modelling and the integration of macro models and energy models, input-output analysis, energy planning models.

Niels A. Kilde, M.Sc. (Chem.Eng.), Senior Scientist. The Danish Steelworks Ltd. 1962-81. Research and quality control (1962), planning and administration (1967), casting department manager (1972), development and energy manager (1977). Risø from 1981. Main activities: Energy use in industry and transport, emission inventories.

Helge V. Larsen, M.Sc. (Elec.Eng.), Ph.D., Senior Scientist. Technical University of Denmark 1974. Storno A/S from 1975. Risø from 1976. Department of Reactor Technology 1976-77. Systems Analysis Department from 1977. Main activities: CHP production, modelling of energy systems, economic models for the oil and gas sector, development of planning models for wind energy, energy planning in Eastern Europe.

Poul Erik Morthorst, M.Econ., Senior Scientist. Risø from 1978. Head of Energy Systems Group 1985-89. Main activities: General energy planning and modelling with emphasis on electricity demand forecasting, economics of renewable energy technologies, especially wind turbines.

Lars Henrik Nielsen, M.Sc. (Phys.,Math.), Senior Scientist. Risø from 1981. Main activities: Probabilistic methods and model development, technical-economic modelling, energy system simulation and assessment of energy technologies, especially renewable energy.

Lise Nielsen, M.Econ., Ministry of Finance 1986-1988 and 1993-1995. Institute of Economics, University of Copenhagen 1988-1993. Risø from August 1995. Main activities: Environmental economics and macroeconomic modelling.

Halldór Pálsson, M.Sc. (Mech.eng.), Ph.D. student at Risø from April 1995. Subject: Planning and control of operation of decentral combined heat and power systems.

Lotte Schleisner, M.Sc. (Mech.Eng.), Senior Scientist. Risø from 1984, Research Section of the Engineering Department. Systems Analysis Department from 1989. Main activities: Assessment of energy technologies (including renewables and hydrogen technologies), life cycle analysis and environmental effects of energy technologies, and externalities from energy systems

Klaus Skytte, M.Sc. (Math. Econ.), Scientist. Risø from February 1996. Main activities: Economic, energy and environmental modelling, operations research.

Integrated Environmental and Risk Management

Kurt Erling Petersen, M.Sc., Ph.D. Risø from 1977. Department of Energy Technology. Risk Analysis Group from 1977-1984. Systems Analysis Department from 1985. Head of Research Programme on Integrated Environmental and Risk Management from 1990. Deputy head of Systems Analysis Department. Main activities: Risk and reliability analysis and treatment of reliability data.

Palle Christensen, M.Sc. (Elec.Eng.), Senior Scientist. Risø from 1962. Electronics Department 1962-86. Department of Information Technology 1986-88. Secretary of Risø's patent council 1973-88. Systems Analysis Department from 1988. Main activity: Risk and reliability analysis and development of computer codes for reliability and safety analysis.

Nijs Jan Duijm, M.Sc. from Technical University of Delft, Holland, Senior Scientist. TNO from 1983- 1995 (Fluid Dynamics Department). Risø from 1995. Main activities: Atmospheric dispersion of hazardous gases, turbulent flows.

Carsten D. Grønberg, M.Sc. (Elec.Eng.). Risø, Electronics Department 1967-78. Safety Department 1978-84. Systems Analysis Department from 1985. Main activities: Human factors, emergency management, risk communication, risk management.

Atoosa Jalashgar, M.Sc. (Elec.Eng.) from Institute of Electronic Systems, Aalborg University (1992). Ph.D. student at Risø and Technical University of Denmark from 1994. Activities:Modelling and analysis of process control systems, function-oriented analysis of technical system

Hans E. Kongsø, M.Sc. (Mech.Eng.), Senior Scientist. Risø from 1957. Research reactor DR2 1957-63, Department of Energy Technology 1963-84. Systems Analysis Department from 1985 until December 1996. Main activities: Computer codes for reliability and consequence assessment, and reliability and safety assessment of nuclear plants and windturbines.

Igor O. Kozin, Ph.D., Obninsk Institute of Nuclear Power Engineering, Obninsk. Risø from August 1994 until June 1996. Main activities: development of reliability data bases, analysis of failure and maintenance data, reliability and uncertainty analysis.

Kurt Lauridsen, M.Sc. (Elec.Eng.), Ph.D.(Nuclear engineering), Senior Scientist. Risø since 1974. Department of Energy Technology 1974-87. Department of Informatics 1987-90. Systems Analysis Department from March 1990. Main activities: Reliability analysis, risk management and nuclear safety.

Frank Markert, M.Sc. (Chemistry), Ph.D., Scientist. Systems Analysis Department from August 1995. Main activities: Risk assessment of chemical plants, toxic effects from releases and assessment of chemical warehouse fire consequences.

Søren Ott, M.Sc. (physics), Ph.D. (Turbulence theory), Senior Scientist. Risø from 1985. Main activities: Models and computer codes for consequence assessment; dense gas dispersion and flame experiments.

Jette Lundtang Paulsen, M.Sc. (Mech. Eng.), Senior Scientist. DTH 1972. Research reactor DR3, 1972-1980. Uranium Extraction project, 1980-1986. Department of Informatics, 1986-1990. Systems Analysis Department from 1990. Main activities: Maintenance and Safety assessment, Displays for control rooms.

Birgitte Rasmussen, M.Sc. (Chem.Eng.), Ph.D., Senior Scientist. The Technical University of Denmark from 1981-84. Risø from 1984. Main activities: Risk assessment of industrial activities, hazard identification, risk management, risk communication.

UNEP Collaborating Centre on Energy and Environment

John Møbjerg Christensen, M.Sc. (Eng.) Ph.D. Danish National Agency of Technology 1980-83. Oilconsult, Consulting Engineers and Planners 1983-84. Risø from 1984. Energy Systems Group 1984-88. Programme Officer, Energy Unit, United Nations Environment Programme 1988-90. Head of the Centre from October 1990. Main activities: energy-environment planning in developing countries, project initiation, UN contacts and coordination.

John M. Callaway, MS (Agricultural and Resource Economics), MA (History). Senior Economist, Battle Pacific Northwest Laboratories (1979-1991), Manager, Hagler Bailly Consulting (1991-1996), with Centre from 1996. Main Activities: Environmental and resource economics, climate change mitigation through forest sector and land use activities, valuation of environmental damages from air pollution, valuation of impacts of climate change on forests and water resources.

Pramod Deo, M.Sc. (Physics) Ph.D. (Infrastructure Economics). Founder Director of state and national level energy institutions, Maharashtra Energy Development Agency (1986-88) and Energy Management Centre (1989-93). Asian Institute of Technology, Bangkok 1985-86 and Energy Policy Consultant at World Bank 1993. From July 1993 with the Centre as Senior Energy Economist. Main activities: energy-environment planning in developing countries, project development and management, technical support to UNEP.

Kirsten Halsnæs, M.Econ., Senior Economist. Danish Ministry of Housing and Building, 1983. Risø from 1987. Energy Systems Group until end of 1992 with the main activities: Methodologies for energy and environmental modelling. From January 1993 with the Centre. Main activities: The Economics climate change mitigation studies, methodologies for climate change assessment in developing countries, environmental economies.

Gordon A. Mackenzie, B.Sc. Ph.D. (Physics), Senior Scientist. Guest researcher at Risø 1974-78. Lecturer at Edinburgh University 1978-79. Energy Systems Group from 1980. 1984 to 1987 Energy Adviser/Deputy Director at Department of Energy, Zambia. From February 1988 until February 1990 leader of Environmental Modelling Group. From October 1990 with the Centre as senior energy planner. Main activities: integrated energy/environmental models, energy and environment in developing countries, environmental database.

Henrik Jacob Meyer, M.Sc. Economist. Rockwool Foundation Research Unit 1990-93. Technical University of Denmark 1993. Risø from December 1993. Main activities: Environmental economics, macro-economic

consequenses of greenhouse gas abatement, externalities in the production of energy, valuation of environmental benefits and damages,

Steffen Rønsholdt Nielsen, M.Sc. (techn.soc.), Ph.D. student. Risø from February 1995. Main interest: climate change mitigation focussing on the impact of alternative land-use patterns in developing countries with a case studie in Ecuador.

Robert Y. Redlinger, B.S. (Civil Engineering), M.S. (Environmental Engineering). Environmental engineer with Kennedy/Jenks/Chilton (USA) 1986-1990; energy economics and policy consultant with Synergic Resources Corporation (USA) 1991-1995; with Centre from 1996. Main current interests: environmental protection in restructured energy markets, private power finance.

Ian Rowlands, B.A.Sc. (Chemical Engineering), Ph.D. (International Relations). Energy Planner. Lecturer at London School of Economics and Political Science 1991-1996. From October 1996 with the Centre. Main interests and activities: International and regional aspects of climate change mitigation, with particular emphasis on Southern Africa.

John K. Turkson. MBA, Ph.D. (Energy Management & Policy). Lecturer at the University of Science & Technology in Ghana (1986-1989). Project Co-ordinator, World Bank/UNDP Renewable Energy Project (1989-1991). From February 1996 with the Centre as a post-doc/Energy Economist. Main Activities: Studies on the environmental implications of Power Sector Reform in developing countries.

Arturo Villavicencio, M.Sc. (Math.). National Energy Institute (Ecuador) 1979-85. Energy Planning Consultant for the Latin American Energy Organisation, CEC and World Bank 1985-88. Energy Adviser at OLADE 1988-90. From May 1991 with the Centre. Main activities: Energy/environmental models, integrated energy-environment planning in Latin America.

Short term Guest Researchers

Beston Chitala, Centre for Energy, Environment and Engineering (Zambia) Ltd., Lusaka, Zambia. Climate change mitigation study for Zambia.

Roger Cooke, Professor in Applied Decision Theory, Delft University of Technology, Holland. Reliability and Safety Analysis.

T. Govindoraj, Ph.D. (Mech.Eng.), Assoc. Professor in School of Industrial and Systems Engineering and Center for Human-Machine Systems Research at Georgia Institute of Technology, Atlanta, USA. Human-centered automation and supervisory control in technologically complex environments with an emphasis on modelling, simulation and design of computer-based systems.

Robert Helmreich, Professor of Psychology at Univ. of Texas at Austin and Director of NASA/Univ. of Texas/FAA Aerospace Crew Research Project. System issues in individual and group human performance, the impact of national and organisational cultures on performance and behaviour.

Per Hokstad, Senior Research Scientist. SINTEF Safety and Reliability, Trondheim, Norway. Reliability and Safety Analysis.

Donella Mutiso, research assistant at African Energy Policy and Research Network (AFREPREN), Nairobi, Kenya. Power sector restructuring in Africa.

Timothy Ranja, research assistant at African Energy Policy and Research Network (AFREPREN), Nairobi, Kenya. Energy and environmental effects of transport in East Africa.

Zbigniew Nahorski, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland. Water Quality problems, mathematical modelling.

Claudia Vivalda, M.Sc. (Nucl. Eng.), Ph.D., Railway Engineering Dept. of the Fiat Industries, Turin. Reliability of man/machine systems, probabilistic safety assessment.

Programmer

Søren Præstegaard, datanom. Regnecentralen 1973-79. Risø from 1979. Datanom with special subject: Optimization completed 1985 at EDP-school, Copenhagen. Working on simulation models, graphics and general user support.

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Thomas Bove (psychol. student). April to August 1996. Assistance with processing of data from human factors experiments.

Joan Dorrepaal (M.Sc.), from January 1995 to December 1996. Development of methods for reliability and maintenance assessment under the Nordic Nuclear Safety Research Programme.

Frederick Juliussen (M.A.). January and February 1996. Assistance with formulating a proposal for instituting a Danish virtual centre for human and sosietal IT research.

Thomas Miller (M.Sc.). January to June 1996. Assistance with field studies at Danfoss A/S on the information needs and search behaviour of professional design teams.

Søren Mensal Kristensen (graduate student) from October 1995 to March 1996. Energy Tariff project.

Per Sieverts Nielsen (M.Sc.) from April 1996. ExternE project.

Roger Williams (Ph.D.). February to May 1996. Design of training systems support of emergency management.

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Abstract (Max. 2000 characters)

The report describes the work of the Systems Analysis Department at Risø National Laboratory during 1996. The department is undertaking research within Simulation and Optimisation of Energy Systems, Energy and Environment in Developing Countries - UNEP Centre, Integrated Environmental and Risk Management and Man/Machine Interaction. The report includes lists of publications, lectures, committees and staff members.

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